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Chinese Jinricksha runner and his carriage. The coat of long grass leaves is cheap and rain-proof.

SOME ODD MODES OF TRAVEL. (See page 264)

Causes and Preventions of Fires in Balloons*

Conclusions Based on Investigations of Fires at Various Army Camps

By Dr. W. F. Swann

During deflation of a Caquot balloon at Fort Sill, the balloon continued to veer where the men had got hold of the manœuvring lines, and almost struck the ground a number of times. Toggles began to be ripped out of the rigging band, and it became evident that the only chance of saving the balloon was to rip the panel.

The ripping panel was ripped and the valve taken out. It was stated that "there appeared to be no gas in the nose of the balloon." When about one-third of the gas had left the envelope there was an explosion, and a blinding flare of flames. The balloon rose about 10 feet in the air all in flames; the cable prevented its rising higher. It then settled to the ground and burned.

Because men handled sand bags, enabling the baloon to be held to the ground, twenty-four men on the leeward side of the balloon were burned. One of the reports says:

After being ripped, about two-thirds of the gas had escaped, when a streak of fire was noticed coming from the top of the balloon traveling down across the ripping panel holes. At this instant the whole balloon burst into flames.

Another report reads:

The balloon was blowing from side to side as it was being hauled down, and when it got near to the ground, it dived over, and the nose struck the ground. The balloon appeared to be losing gas as the nose was caving in. Five holes were observed on one side of the balloon. A flash of fire appeared at the nose of the balloon, and spread almost instantaneously over the balloon.

A photographer happened to be on hand at the time, and his report describes the forward third of the balloon as being the part which first burst into flames, the flame being instantly driven back by the wind so as to envelop the entire bag.

The balloon had apparently lost a great deal of gas, and an amply sufficient explanation of the formation of an explosive mixture in the balloon is to be found in the removal of the valve, thus forming an opening at a place other than at the highest point. The fact that the valve was removed when the ripping panel was open enormously aggravated the circumstance, resulting in an outflow of hydrogen at the ripping panel, and an inflow of air at the valve. The small holes which had been torn in the side of the balloon possibly contributed in some slight degree to the effect; but their influence would probably be small compared with that caused by removing the valve.

Two of the reports implied a flabby condition at the nose of the balloon, indicating that the pressure outside the balloon at the point was greater than the pressure inside. One report speaks of a "flash of fire occurring at the nose of the balloon," and the photographer's report speaks of the forward one-third of the balloon as being the first part to burst into flames. Both of these accounts are in harmony with the conclusion that the forward part of the balloon was the seat of the explosive mixture.

The first of the above abstracted reports speaks of a "streak of fire coming from the top of the baloon, traveling down the ripping panel holes." The current of gas established between the ripping panel and the valve opening by the entrance of air at the latter and the exit of hydrogen through the former would result in an explosive mixture all along this path, so that a flame started at one place would propagate itself almost immediately over this region, and it would be difficult to say from the general appearance just which way the explosion traveled.

There was a high wind, and as there is a great deal of dust at Fort Sill the conditions were just such as to be favorable to the electrification of the balloon by the dust blowing upon it. This conclusion is supported by the statement in one of the reports, to the effect that a spark of considerable intensity was obtained from the winch, and by the reports of the Radio Officer, who spoke of the electro-static conditions prevailing on this day. I would call attention to the following:

In order for the spark to have resulted in explosion it was necessary for it to have occurred at a place where there was an explosive mixture. There would be an explosive mixture at the rip-panel where gas was discharging into the air, and there would be an explosive mixture at the appendix opening, and at the other openings which had been accidentally made; for, in spite of what has already been said with regard to the inflow of air at these lower openings there would be periods when gas was forced out of them as a result of the rolling and general agitation to which the balloon was subjected. Again, the irregular nature of the gusts of wind might well result in enough hydrogen being from time to time blown down to cause an explosive mixture at any point where the men were working, especially when we remember that 5 per cent. of hydrogen will render the mixture explosive.

The spark certainly did not occur during the ripping of the panel, for it was a considerable time after this that the explosion occurred. It is not likely that it occurred at the rip panel at all; for in spite of the strong electrification to which the balloon was probably subjected, there was no opportunity for a spark to pass between two conductors or between a conductor and the fabric in this region, since no conductors were present there.

At the ground level there was, however, plenty of opportunity for sparking, as for example between two men who had become charged to different extents by the particles of dust in the air, by friction resulting from rubbing against the balloon, or by discharge of a portion of the balloon's surface by direct contact with it. Again a spark may have occurred between one of the men and the charge balloon fabric, or one of the conductors, metal hooks or ropes associated with the sand bags. If it so happened that any part of the valve attachment was not removed from the valve opening there would have been a good opportunity for a spark to pass between this part and any one who touched it.

Thus the conditions were such that there was ample opportunity for the presence of small quantities of explosive mixture and of sparking of various places outside the balloon. The ignition of the mixture at a point in the vicinity of one of the openings would result in the propagation of the flame into the balloon in view of the existence of an explosive mixture there. The main explosion would of course result from this latter mixture in view of its having collected in large quantities. The explosion would rip open the fore part of the balloon and thus expose the remainder of the hydrogen, which would become ignited and burn until it has been consumed, with a speed rather slow compared with the explosion.

The writer is thus of the opinion that the primary cause of the major explosion which destroyed the balloon was the explosive mixture which formed inside as a result of there being an opening at the valve while gas was discharging from the rip-panel. The conditions were favorable to the formation of electric sparks, and the writer is of the opinion that such a spark was formed in a small quantity of explosive mixture on the outside of the balloon near one of the openings, with the result that the explosive flame was propagated through the opening to the main body of the explosive mixture inside.

Another case is that of a free balloon of 9000 cubic foot capacity, leaving Fort Omaha at 8:30 A.M. on June 15, 1917. The weather was calm and the balloon traveled only 9 miles in one hour. At 10:40 A.M. the pilot made a landing. He then ascended to an altitude of 6000 feet and again landed near Nebraska City under a mild wind of less than 15 miles per hour.

The landing was made without ripping the panel, and the pilot got out of the basket, pulled down the net so as to reach the valve, and unhooked the valve spring so as to facilitate the escape of the hydrogen. He then started to pull the net so as to get the valve once more to the top. When the valve was approximately at the desired position, he, to use his own words, "Heard the characteristic sound of ignited hydrogen," and, realizing the possibility of sudden explosion, threw himself down on the ground to protect his face. The explosion followed immediately; the envelope was gone in a few seconds.

I would impress upon the reader the following facts:

The region surrounding the place where hydrogen escapes into the air is always the seat of an explosive mixture. The "characteristic sound of ignited hydrogen" referred to by the pilot evidently corresponds to the "pop" or miniature explosion resulting from the ignition of the explosive gas at the valve opening. The valve being open, and the appendix being also open, the conditions were favorable for the formation of an explosive column of gas between the two openings.

So long as the initial velocity with which a flame would start be propagated through this explosive column (a velocity of the order of magnitude of one or two meters per second) was less than the velocity of efflux of the gas from the valve, the explosion would be unable to propagate itself, or "strike back" into the balloon.

This would appear to be the condition prevailing at the instant when the ignition was first noticed. At this time the pilot was presumably pulling down on the net. On hearing the initial miniature explosion he released the net. This would produce a sudden diminution of the pressure in the balloon and consequently a diminution of the velocity of efflux of gas, enabling the flame to strike back into the balloon and explode the whole of the explosive mixture contained therein. In this way the major explosion is accounted for as occurring an instant after the initial minor explosion, a circumstance which seems to be implied in the pilot's report.

The major explosion probably represented the combustion of the explosive mixture in the column joining the two openings, and in the regions to which air had diffused from this column. A quantity of hydrogen of a degree of purity comparable with that in the balloon at the moment of descent would yet remain, and this would burn with a speed relatively slow compared with that of the explosion, a circumstance borne out by the pilot's statement that the envelope was consumed "in a few seconds."

The hydrogen used for a free balloon is usually taken from a kite balloon when the purity is insufficient to provide a satisfactory lifting power in the latter. Further, in descending, a free balloon will to some extent take in air through the appendix, although the automatic construction of the latter by the increase of external pressure minimizes the influx of air. However, there is always a certain possibility that the gas in the free balloon is explosive. That such was not the case in the instance under discussion, however, is borne out by the fact that the gas burned for a few seconds after the major explosion, and we are thus lead to the conclusion that the primary cause of the explosion inside the balloon was to be found in the column of explosive gas which originated as a result of the appendix being open while the hydrogen was discharged from the valve.

The primary origin of the spark was probably the electrification of the surface of the balloon by the friction resulting from pulling the net over it. The spark might arise in several ways. It might occur between the fabric and the net rope; or, some part of the valve which was conducting but was insulated from other conducting parts might spark to one of these parts as a result of its having become charged by leakage from the charged envelope.

The first ignition of the escaping gas was caused by an electric spark which occurred in the vicinity of the valve and the major erplosion was caused by the striking back of the flame into the explosive column of air which resulted from the presence of two openings in the balloon, at different angles.

It was on Christmas Day, 1917, that an explosion occurred which destroyed a Caquot balloon during deflation, immediately following partial inflation at Fort Sill. The weather was dry and cold and slight snow was falling. The balloon was a new Caquot, just received from the manufacturers. After it had been unpacked from its case, spread out on the floor of the hangar, inspected carefully, and attached to the hydrogen cylinder trucks, the gas was carefully turned on, and the inflation proceeded under the direction of experienced officers.

The first indication of trouble was a slight "pop" which occurred before the inflation reached the valve. No smoke resulted, and nothing more was thought of it.

Later, when about 15,000 cubic feet of gas were in

(*Concluded on page* 280)

*From *U. S. Air Service.*

TO OUR SUBSCRIBERS

We are still laboring under the tremendous handicap imposed upon us by the strike of pressmen and compositors and again we are obliged to publish a double number of the Scientific American Supplement *this time combining the issues of November 1st and 8th. We hope however to resume our weekly schedule with the issue of November 15th, which however will probably be somewhat delayed. We wish to thank you for your indulgence in these distressing conditions.*

Stunt Flying and the Commercial Pilot*

Ability to Perform Daring Maneuvers in an Emergency

By Lieut F. T. Courtney, Late R. A. F.

WHILE there is a number of people who are content to take the present risks of aviation for sporting or semi-sporting purposes, this is far from being true commercial aviation. Immense as has been the advance in matters of reliability in aeroplanes and their engines, there still remains a factor of uncertainty. Engines still fail in flight; they still fail near the ground, and so long as the resultant crashes are the fairly common occurrence they now are the ordinary man will refuse to trust the aeroplane as a business proposition. I think it will be admitted that this element of public doubt, immensely increased by every crash to a commercial aeroplane, is one of the greatest obstacles to the rapid development of commercial flying.

Clearly, therefore, it should be the first consideration of an aerial enterprise, whether of a pleasure or of a business nature, to take the greatest possible pains to avoid any form of crash to its machines. "Well, of course, that is the very first thing we always do," says the commercial firm. Is it?

It is going to be a considerable time before engines, either single or multiple, and their accessories reach the very high degree of reliability which is necessary. So that the only means left to avoid crashes is *to employ the type of pilot who will, if it is humanly possible, be certain to bring safely through any difficulties, his machine or at least its occupants.* Even should only such emergency arise to a pilot in a year that principle is justified. And unquestionably that principle is not now universally in operation.

Some weeks ago the Prince of Wales went for a stunt flight with Col. Barker, V.C., and an evening paper published this fact with appended comments to the effect that the Prince ought to know better. "There were already enough deaths from commercial aviation without silly stunt flying receiving royal approbation," or words to that effect. And an aeronautical paper reprinted this article with an approving headline.

Now it is a complete mystery to me that, even now, it fails to penetrate many minds, aeronautical and otherwise, that by far the greater number of serious crashes would never have taken place had the pilot had the skill, lightning judgment, presence of mind and nerve which stunting gives to a pilot who has intelligently learnt to stunt.

Stunting never was and never will be a public danger. The pilot who learns his stunting with due regard to its difficulties and to the practice required becomes an excellent and safe pilot. The pilot who stunts recklessly soon kills himself (rarely anyone else) and ceases to affect this argument. That unpopular man who dives and "zooms" at people on the ground to "put the wind up them" is never a stunt pilot. If he were he could effect his object, without any danger to the people, by some real stunting, instead of by the simple, unskilled, fore-and-aft movement of the joy-stick.

I know some people will never be convinced that stunting, especially low-down stunting, can ever be a matter of very careful, if apparently reckless, flying. The stunting pilot rarely has any sympathy accorded him. While generally enjoying the spectacular side of his flying, most people regard the pilot as an irresponsible fool, with more animal courage than imagination and sense, anxious to get sensation or applause at the risk of his neck; while the man who stunts low down, the abhorred of wing and squadron commanders, is generally considered the last word in objectionable idiocy.

Now, in the interests of the safety of flying, it is time these ideas were entirely reversd.

Allowing for certain rare exceptions, the real stunt pilot, perhaps unconsciously, follows certain rules of safety. He has ever in his mind certain possibilities of trouble, such as engine failure, and is ready to deal with them immediately. He is continually putting his machine in extraordinary positions and righting it again. He is discovering the behavior of a machine in those extraordinary positions, which a pilot who does not stunt never discovers. He is carrying his flying further toward perfection, which the non-stunter never does. Incidentally he is enormously improving his nerve.

How often has not the stunt pilot saved himself and his machine by some violent sideslip to shorten his distance, or by a vertical bank at a low height where the non-stunter does that fatal flat turn, or by some manœuvre which he would not dare to attempt had he not done it many times before in the course of his "silly" stunting? How often has he not, promptly and easily, brought his machine out of some difficulty with which the non-stunter (generally, curiously enough, called a "safe" pilot) would be powerless to deal. The fact that he has done these stunts on his small machine makes little difference. Once a pilot masters the principles and details of stunting, he can apply them to a large machine to the fullest extent of its strength and manœuvrability.

One of the greatest and most dangerous fallacies of commercial aviation is the idea that the scout-pilot is of little use for passenger carrying, which is supposed to be a work of the heavy machine pilot. The pilot who can really fly a small machine finds the large types child's play. The reverse is by no means the case, which proves that the scout pilot is the better flier. As illustrating my point, it is a fact that during the war a large number of bombing machine pilots were those turned down as unable to fly the lighter machines. If a man cannot fly, easily and well, a small light machine, there is something missing in his flying skill, and it is not good enough for public safety that he should be considered a commercial pilot.

In order to ensure that a pilot should be able to extricate his human cargo from any difficulties he must clearly be able to use to the very limit the manœuvring powers of an aeroplane. He must be able to do this promptly, accurately, and almost unthinkingly.

If he cannot stunt it is clear that he cannot fulfil those requirements. Therefore, the passenger-carrying pilot should, when off duty, be expected to indulge in plenty of hard stunting. Considering that most crashes are due to engine failure low down, then the lower a pilot can manage to stunt the better will he be qualified to avoid crashes, and the more acrobatic are his stunts, the less difficulty will he find in more ordinary situations. Also, an dthat is where the commercial firm must avoid being economical at the public expense, this stunting involves a certain amount of personal risk and a very good quality of pilot, and the price must be paid.

A widespread idea, which is the exact reverse of the truth, is that the peace pilot requires less skill than the war pilot, and that there is a great surplus of pilots for commercial work. It is true that the peace pilot will have less occasion to use his skill than the war pilot, but his skill will have a higher proportional value. There was always a use for the moderate pilot in war, but for commerce he is not good enough, not for some time, at any rate. The skilled pilot requires, besides his skill, other qualities which go to form a combination which is none too common among the great number of war pilots. I do not even say that every stunt pilot is a suitable commercial pilot, but I do say that every commercial pilot should be able to stunt.

I know many first-class pilots refused commercial jobs. Knowing their skill, they ask for a respectable salary. I actually heard a prospective employer of pilots say: "But I have offers from pilots to fly for us for £250 a year; look at this letter." There it was, as usual; the good old heavy machine pilot, safe while his engines ran well and everything was all right, but dead certain for a bad crash the moment anything went seriously wrong. Often when a first-class pilot asks for a reasonably paid job he is told that the heavy machine pilot is wanted. One of the best pilots I know of was refused a job because he had not flown twin-engine machines.

The whole argument boils down to this: that intelligent stunting, far from being idiotic, represents the perfecting of a pilot's skill in handling an aeroplane; a pilot can be called first-class only when his flying is reasonably near to perfection; and only a first-class pilot is good enough for the safety of passengers and the consequent progress of commercial flying.—From *Flight*.

* *Flight*, September 4, 1919.

Sound Emission from Airscrews.*

By Prof. G. H. BRYAN, F.R.S.

When airscrews were run on the large whirling arm of the Royal Aircraft Establishment the sound emitted showed only faint traces of the low bass note, resembling an organ tone, which is often conspicuous when aeroplanes are flying overhead; on the contrary, the principal sounds of definite pitch heard were roughly of 400, and in lesser degree 200, vibrations per second, the calculated pitch due to the revolution of the blades being about 70, 40 and 30 per second in the several cases. When, however, the screws were mounted in *fixed* bearings on the spinning tower, and the sound observed in the neighborhood of the plane of rotation, the low bass notes were very conspicuous, and agreed closely with the number of beats per second calculated from the revolution of the blades—namely, 50, 55, and 60 for a three-bladed screw, and 33, 37, and 40 for a two-bladed screw at 1,000 1,100, and 1,200 revolutions per second. With the two-bladed screw running at the higher speed the octave (say 80 per second) was also conspicuous.

In the case of an airscrew of which the tip velocity exceeded the velocity of sound (say 1,180 feet per second), an extremely unpleasant crackling sensation was experienced in the neighborhood of the plane of rotation.

The observations lead to the conclusion that when an aeroplane is observed flying sideways the low organ-pipe tones that are observed are due to the direct action of the blades of the screws upon the air, but their intensity decreases as the angular distance of the observer from the plane of rotation increases, thus accounting for the rise and fall of the sound with the rotary oscillations of the aeroplane, as well as for the unfavorable results obtainable in the whirling arm tests. As, however, the pulsations of an eight-cylinder engine agree in frequency with those of a four-blade screw, tones of nearly the same pitch may also be produced by the engine, and these are often heard when an aeroplane is receding. They differ in tone quality from those due to the screw, and the motion of the machine gives rise to a slight difference in pitch.

In the case in which the tip velocity exceeds the velocity of sound, the disturbances produced in three different positions of the tip may reach the observer at the same instant during a certain portion of each period, and at the beginning and end of this portion the disturbance *theoretically* becomes infinite, thus accounting for the unpleasant sensation and its limitation to a very narrow zone near plane of rotation.

A systematic study of the phenomena involves an examination of the theoretical sound effects due to moving surfaces and moving sources, and certain difficulties present themselves which were evidently anticipated by the late Lord Rayleigh in his "Theory of Sound." So far as these difficulties are due to physical considerations, I find that they in great measure disappear, when instead of working with the *velocity potential* we notice that it is on the *condensation* that the sound effects mainly depend. At this stage the mathematical work becomes rather heavy and confirms Messrs. Lynam and Webb's use of Bessel's Functions in this connection. I have, however, given a simple graphical construction for the vibration curve due to a revolving source, with special reference to cases in which the velocity of revolution exceeds the velocity of sound. The fluctuations producing the effect of sound are due partly to the varying distance of the source from the observer, and partly to the variations in the interval between the time of emission and the time at which the disturbance reaches the observer. An important practical application consists in determining theoretically the law according to which the intensity of sound should diminish with the distance as well as its dependence on the rate of revolution. So far as can be ascertained at present, the effect of a revolving source is more like a doubled than a variable fixed source, the condensation due to the former varying as the inverse square, and of the latter as the inverse first power, of the distance. On this assumption the sound of the exhaust should be heard further off than that of the airscrew, even when both are of the same pitch.

* *English Mechanic and World of Science.*

Atoms and Molecules*

An Elementary Explanation of Modern Methods of Proving Their Existence

By Jean Becquerel, Professor at the Museum of Natural History in Paris

The idea of the discontinuous structure of matter is a very ancient one. More than five hundred years before our era the philosophers Leucippus, Democratus of Abdera, and Moschus of Sidon conceived the idea that matter is formed of indivisible and eternal atoms which move in infinite space. In a celebrated letter Epicurus wrote to Herodotus that there exist two kinds of bodies, composite bodies and the elements which compose them; these last are indivisible, immutable, and in perpetual movement; they link themselves together to form bodies. In the admirable poem written by Lucretius we find similar doctrines. Finally the ideas of Descartes and Leibnitz concerning the structure of matter can be traced to very similar concepts.

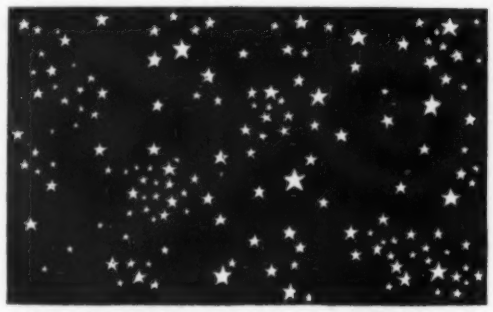
In this study I propose to show how the progress of science has enabled us to develop and bring to a focus the theories concerning which the ancient philosophers had an intuition, and also to set forth the facts which have made physicists and chemists feel certain of the existence of the atoms of which all the elements are formed. The fundamental laws of chemistry lead us to the logical belief that matter is discontinuous. Everyone knows that chemical substances are divided into *elements* which cannot be decomposed into other substances, and *compound substances*, which are formed by the union of several elements. Thus hydrogen and oxygen are elements, while water, formed by their chemical combination, is a compound body.

The *law of definite proportions* which we owe to Proust teaches us that *two elements combine with each other to yield one or more compounds according to well-known proportions which are not capable of varying in a continuous fashion;* for example, if we burn 2 gr. of hydrogen we consume 16 gr. of oxygen and we obtain 18 gr. of water. These are fixed proportions: It is not possible to obtain a body having properties very similar to those of water by slightly changing the proportions of the hydrogen and oxygen. There is, however, a second possible combination: namely, 2 gr. of hydrogen and 32 gr. of oxygen will unite to form 34 gr. of hydrogen peroxide. Here again the proportions are fixed, but there is a discontinuity between these two compounds, both obtained by the union of hydrogen and oxygen, and hydrogen dioxide is, in fact, a substance very different from water. It is not by mere chance that the quantity of oxygen which combines with the same quantity of hydrogen is *exactly* twice as great in one case as in the other: It is a particular example of the law of Dalton, known as the *law of multiple proportions*, which may be thus expressed:

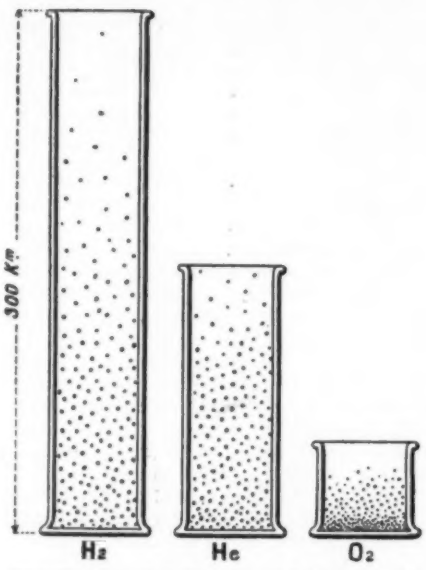
If we observe all the compounds containing, among others, two elements, A and B, and if we compare in all the compounds the weights of B which are combined with the same weight of A, we find that the ratios between these weights of B are always simple and very often equal.

For example, in compounds containing oxygen and nitrogen we find weights of oxygen which are capable of uniting with 28 gr. of nitrogen are 16, 32, 48, 64, 80 and 96 gr. These numbers are proportional to 1, 2, 3, 4, 5, and 6 respectively. To explain these laws Dalton assumed that each element is formed of *atoms*, very small particles which are identical with each other in the same element but differ in different elements and which remain indivisible even when they unite to form chemical combinations.

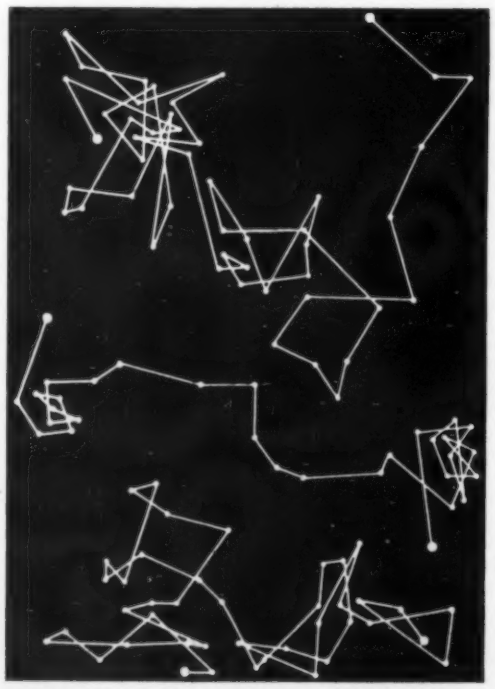
The atom of an element is the smallest quantity of matter which is characteristic of that element and which is capable of entering into combination; the atoms unite with each other *even in the elements*, and their union forms a *molecule*. The molecules of the same body are identical with each other, whether the body is simple or compound. The molecule of a compound body is formed by the union of the atoms of at least two different elements; we now know that the molecule of an element may be composed of a single atom[1] (mono-atomic bodies, such as mercury), and that it may also be composed of 2, 3, or 4 atoms, or even more (di-atomic, tri-atomic, tetra-atomic, etc.).



Atomic bombardment rendered visible by the scintillation of a phosphorescent screen



Distribution of molecules of hydrogen, of helium and of oxygen, introduced in equal numbers in three test tubes maintained at uniform temperatures



Graphic representation of the disordinated movements of three molecules.

The direction of the trajectory changes each time that the molecule encounters any obstacle whatever.

The atomic hypothesis immediately makes clear the laws of Proust and of Dalton. These laws result from the fact that a molecule contains a whole number of atoms and cannot vary except by the entrance or the exit of at least one whole atom. Thus, if we assume that the weight of an atom of hydrogen and of an atom of oxygen are in the ratio 1:16, that the molecule of water contains 2 atoms of hydrogen and one of oxygen, and that that of hydrogen dioxide contains one more atom of oxygen, then the proportions of these two elements in water and in hydrogen dioxide will always be as 2:16 and 2:32; these will be fixed proportions with no possible intermediate, and there will be exactly twice as much oxygen in the hydrogen peroxide as in the water.

In order to know the number of atoms which compose a molecule, chemical analysis is not sufficient. here there come in play the *law of Gay-Lussac and the hypothesis of Avogadro*. According to the former *the volumes of gases which combine with each other* (measured at like temperature and like pressure) *bear a simple ratio to each other.* Thus 2 liters of hydrogen will combine with one liter of oxygen to form two liters of water vapor. This law in connection with those which relate to changes of volume under the influence of pressure and of temperature led Avogardo to formulate, as early as 1811, the following hypothesis: *All gases contain the same number of molecules in the same volume, under the same conditions of temperature and of pressure.*

It would take too long to explain here how this hypothesis has made it possible, knowing the proportions by weight of the elements in different compounds to determine on the one hand the relative weights of atoms and on the other the number of atoms which are contained in a molecule. The relative weights of atoms, expressed by taking as a unit the weight of the lightest, i.e., the atom of hydrogen, are called atomic weights. Hydrogen $H = 1$; helium $He = 4$; oxygen $O = 16$; nitrogen $N = 14$, etc.

The molecular weight of a body is evidently equal to the sum of the weights of the atoms which form the molecule. Hydrogen (di-atomic) $H_2=2$; helium (mono-atomic) $He = 4$; oxygen (di-atomic) $O_2 =32$; water $2H + O$ (usually written H_2O) $=2+16=18$, etc.

According to Avogadro's hypothesis, 2 gr. of hydrogen, 4 of helium, 32 of oxygen, 18 of water vapor, etc., occupy the same volume under the same pressure and at the same temperature, and contain the same number n of molecules. At a temperature of 0°C. and at ordinary atmospheric pressure this volume is equal to 22.400 liters.

To the number of grams of a body equal to the figure which represents its molecular weight we apply the term *molecule-gram* of the body; this is the weight of 22.400 liters of the body in a state of gas. The molecule-gram contains n molecules and n which is the same in all bodies is termed Avogadro's number.

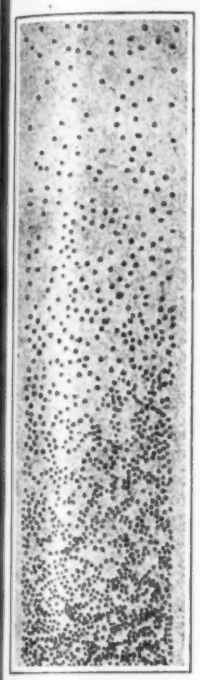
The knowledge of Avogadro's number involves the determination of the weights of molecules and of atoms—no longer their relative, but their actual weights. The actual weight of the atom of hydrogen $= 1/n$, that of the atom of oxygen $16/n$, that of the molecule of water $18/n$, and so on. We shall see how it has been possible to determine in one manner or another the number of Avogadro and to discover the actual value of molecular magnitudes.

The phenomena of diffusion prove that molecules are not immovable. For example, take two vessels, one above the other, the lower one containing carbon-dioxide and the other hydrogen, and establish a communication between them. In spite of the difference of density and although the hydrogen, which is much lighter than the carbon-dioxide, has been placed in the upper vessel, we find, after the lapse of a certain time that the two gases are in a state of intimate mixture in both vessels. This is the celebrated experiment of Berthollet. It furnishes obvious proof that the molecules are in motion.

* Translated for the SCIENTIFIC AMERICAN SUPPLEMENT from *La Science et la Vie* (Paris).

[1] In this particular case the molecule is identified with the atom.

A theory which is already very old, i. e., *the kinetic theory of gases*, has enabled us to explain the properties of the latter; it has led to a first determination of the number of Avogadro and of molecular dimensions. The kinetic theory assumes that the molecules of a gas move freely in a straight line with a speed which depends upon the weight of the molecule and upon the temperature; the direction of movement of a molecule changes each time that it strikes an obstacle, or that it enters into collision with another molecule. The result of these shocks, which are very frequent, is that the *movement is completely disordinated*. Molecules have been compared to very small spheres, perfectly elastic, and having dimensions which are very small with respect to their average distances from each other (which ceases to be true when the gases are greatly compressed). This concept of molecular agitation immediately enables us to understand why a gas fills uniformly the entire volume which contains it and why it exerts a pressure upon the walls of the container: *the pressure is due to the molecular bombardment.*



Natural distribution of the particles in an emulsion in respect to the altitude of the liquid column.

The law of Mariotte, which states that for a given mass of gas the pressure varies in inverse ratio to the volume (at a given temperature) is almost evident: Let us imagine a gas occupying a certain volume under a certain pressure; make the volume n times as great while keeping the temperature constant; the number of molecules in each cubic centimeter will be only one nth as great; therefore the product of the pressure by the volume has remained strictly constant.

By the application of the law governing the shock of perfectly elastic bodies and supposing the molecular movement to be completely disordinated, it has been demonstrated that for a given mass of gas the constant product of the pressure by the volume is equal to 1/3 of the product of the total number of the molecules multiplied by the mass of a molecule and also by the square of the *average* rate of speed [2]. This relation at once enables us to calculate the average speed of molecules. We know, in fact, the mass of the gas employed; we can measure the product of the pressure by the volume and we also know the product of the number of molecules by the mass of one molecule, for this product is simply the mass of the gas. We shall indicate the results farther on. It is possible for the individual speeds of molecules evidently to vary greatly from the average speed, since they are modified at each collision. However, the average remains constant.

In order to compare the different gases we will take a molecule-gram of each of them —according to the foregoing observations all these molecule-grams occupy the same volume under the same pressure and at the same temperature, and contain n molecules (Avogadro's number). Let us now vary the temperature: the laws of gases have proved that the product of the pressure by the volume is equal in all gases to a well-known constant (called the constant of gases) multiplied by the *absolute temperature*. This is the temperature of 273 degrees below zero centrigrade. (The absolute temperature of melting ice is 273 degrees, that of boiling water 373 degrees.)

Upon comparing this result with that which is a consequence of the kinetic theory it is readily seen that the average live force of a molecule (half the product of the mass by the square of the average *speed is the same for all gases at the same temperature and varies in proportion to the absolute temperature*, or in other words the average speed is proportional to the absolute temperature and inversely proportional to the mass of the molecule (and consequently to the density of the gas).

The product of the absolute temperature by a universal constant represents, therefore, the average live force of any molecule whatever. Absolute zero is the lowest temperature of which it is possible to conceive; it is a limit which we can never expect to attain since it corresponds to absolute rest. . . . We know, therefore, the average speed of the molecules of the gas. It remains to determine the *average free distance traversed*. The calculation of this results from the knowledge of the *viscosity* of gases. Let us imagine two strata of a gas moving parallel to each other but with different degrees of rapidity; the incessant bombardment of the molecules has a tendency to equalize these rates of speed; consequently, there is a friction of the two layers of gas upon each other. This friction has been measured and it has been demonstrated that it is proportional to the density, to the average rate of speed, and to the free distance traversed. Knowing the latter we can easily calculate the *average number of collisions* of a molecule per second; it is the quotient of the average rapidity of this molecule by its average free distance travelled.

Finally, it is possible to calculate the dimensions of a molecule if we suppose it to have a spherical form. Clausius and Maxwell have established theoretically a primary relation between the number of molecules, the diameter of each of them, and the free distance traversed; this is easily understood since the larger and the more numerous the molecules the smaller the free distance traversed must be. A second relation between the number of the molecules and the diameter is given by the measurement relating to the compressibility of gases. From these two relations we derive the diameter of a molecule and the number of Avogadra. We are in possession consequently of all the molecular magnitudes. Below are stated the results which they express.

Average weight of speed at ordinary temperature: several hundred meters per second (oxygen at 0°C. = 425 m.; hydrogen, 1,698 m.).

Average free distance traversed: order of magnitude equals one ten-millionth of a millimeter (oxygen 0.000106 mm.).

Average number of collisions of a molecule: several billions per second (oxygen equals 4,065 millions).

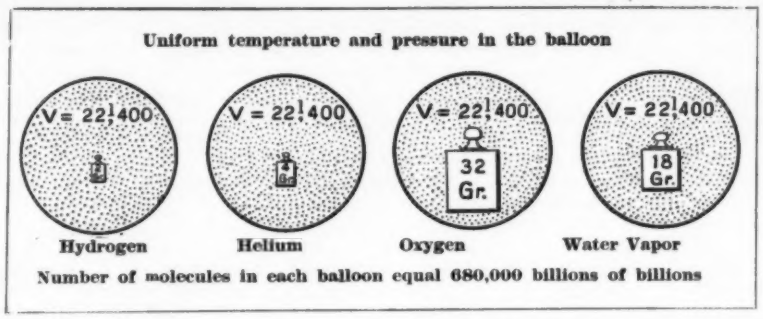
Diameter of molecules: a few ten-millionths of a millimeter (argon 2.85/10,000,000 mm.).[3]

Number of Avogadro: by the kinetic theory this is 63 times 10^{22}, but we shall adopt 68 times 10^{22} as a result of the experiments of Monsieur Jean Perrin, to whom we shall refer further on.

Mass of an atom of hydrogen:

1.5 10^{-24} gr. 1.47/1,000,000,000,000,000,000,000,000 grams.

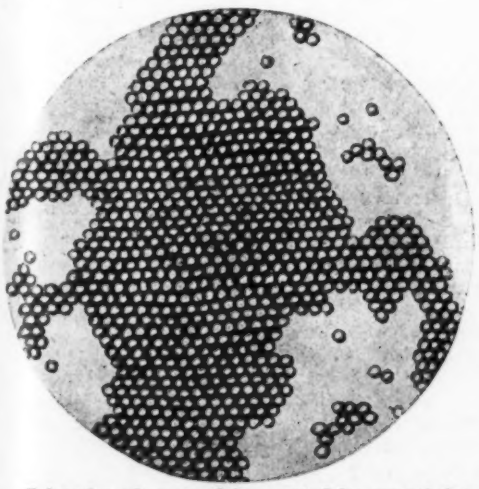
Thus we can form an idea of the indescribable chaos presented by a gas in normal condition: *thirty billions of billions of molecules in a cubic centimeter;* movements absolutely disordinated; rates of speed variable within large limits, but equal



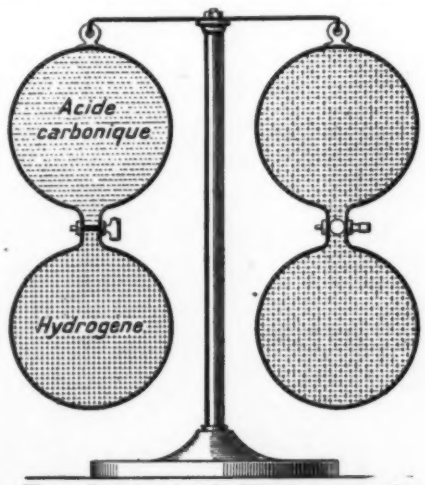
Two grams of hydrogen, four grams of helium, thirty-two grams of oxygen, eighteen grams of water, etc., occupy the same volume, according to the hypothesis of Avogadro, provided the pressure and the temperature are uniform.

[2] We are here concerned with the average quadratic rate of speed, i. e., with the square of the average of the squares of the rates of speed. The mass is the weight divided by the acceleration due to the force of gravity. It is this which is measured by the balance, which compares the masses and does not measure the weights; but since the masses and the weights are proportional *when in the same place* we are commonly in the habit of speaking of weights instead of masses.

[3] This calculation is made for a mono-atomic gas since we cannot assume that molecules are spherical except in the case of mono-atomic bodies.

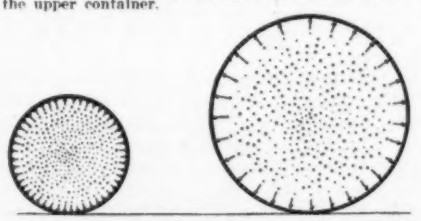


Spherules of an emulsion, sorted by centrifugal for the purpose of calculating the number and the mass of the molecules contained in the molecule-gram of the substance studied.

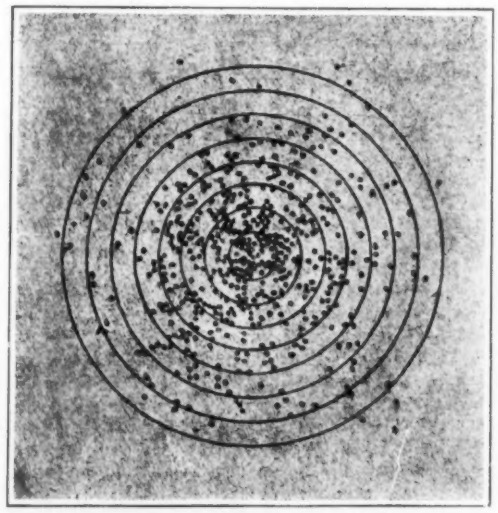


The phenomena of diffusion prove that molecules are not immobile.

If we establish a communication between the two receptacles we find after the lapse of a certain time that the two gases are intimately mixed (see at the right) although the carbon di-oxide, which was much lighter than the hydrogen, has been placed in the upper container.



Gas pressure is due to molecular bombardment of the walls of the container. If the volume of the container is augmented without changing the quantity of the gas, there are fewer shocks on the walls and the pressure consequently diminishes.



A Plane Image of the Brownian Movement

Taking horizontal displacements of the grains in agitation so as to give them a common origin, the extremities of the vectors are distributed around this origin as bullet holes around a bull's eye.

to a few hundred meters per second in the great majority of cases; average distance traversed by molecule between two shocks about one ten-millionth of a millimeter; several billion shocks per second for each molecule.

These figures stupify us either by their enormity or their minuteness. Here again are two results which are as curious as they are unsuspected:

The *total* surface of the molecules contained in a cubic centimeter amounts to several square meters.

If the molecules of argon contained in a cubic centimeter were placed end to end in a single line they would go round the earth two hundred times.

These two results are a consequence of the immensity of the number of molecules.

The knowledge of the number of Avogadro involves, as we have already said, that of all the molecular masses, which we obtained upon dividing this number by the molecular weight.

* * *

The success of the kinetic theory is hardly sufficient to carry with it complete conviction, by reason of the numerous hypotheses upon which it is based. This conviction cannot be acquired until more tangible phenomena enable us to verify the hypothesis of molecular movement and until, on the other hand, phenomena entirely different in nature lead to the same value of the number of Avogadro. Among such phenomena we must place in the first rank the curious and interesting one known as the Brownian movement.

In 1827 the naturalist Brown called attention to the fact that small particles suspended in a fluid are animated by disordinated movements. A study of these was made in 1888 by M. Gouy, from whom I will borrow the following description of the phenomena:

"If the particles are numerous it will be seen that everything is in movement throughout the whole field of the microscope. It is a sort of trembling, or general trepidation, which forms an extremely striking spectacle. Each particle undergoes a series of displacements, which are rather difficult to describe because they are essentially irregular . . . we perceive also that each of them revolves upon itself regularly . . . everything happens in a word as if each particle were subjected to a series of absolutely fortuitous impulsions oriented indifferently in every possible direction."

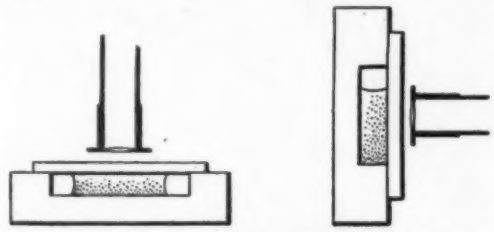
The smaller the particle the more lively these movements are. *The strangest characteristic of this Brownian movement is that it never ceases and that it is entirely spontaneous.*

Numerous physicists have believed that the Brownian movement reveals the agitation of the molecules of the fluid in which the granules are suspended. The molecules of the fluid rush incessantly against the granules and the smaller and more tenuous the particles are the less chance there is of an equilibrium being produced between the shocks. In a word, *the particles held in suspension participate in the general and incessant agitation of the molecules of the fluid.*

It is this hypothesis which M. Jean Perrin has succeeded in verifying (1908) by the remarkable experiments which led him to a more correct determination of the number of Avogadra, i.e., let us repeat, of the number of molecules contained in the molecule-gram.

The laws of gases are applicable to all molecules, whatever their dimensions may be. Van t'Hoff has, in fact, extended these laws to solutions: sugar dissolved in water, for example, behaves exactly as the same number of molecules would do if they occupied in the gaseous state the same volume as that of the solution. The heavy molecule of sulphate of quinine containing more than 100 atoms behaves exactly like the light molecule of hydrogen. Since this is true, why cannot we extend the laws of gases to emulsions? In this way the hypothesis of the kinetic theory might be controlled by direct observation. The microscopic grains which are small enough to participate perceptibly in the movement of agitation and yet sufficiently large to be measurable would form, as M. Jean Perrin has justly observed, "the intermediary, the indispensable relays between the masses of our scale and the molecular masses."

As we have stated, the average live force of any molecule whatever is equal to the product of the absolute temperature by a universal constant. This constant is equal to one and a half times the quotient of the constant of gases (*vide* the foregoing) by the number of Avogadro. Hence, if the granules of an emulsion take part in the molecular agitation they must possess the same average live force as the molecules and since these particles are visible under the microscope it is possible to measure this live force; consequently we thus obtain the tient of the constant of gases (*vide* the foregoing) number of Avogadro. *If we always find the same number for all kinds and sizes of particles, whatever the temperature may be, and if, furthermore, this number approximates that which results from the kinetic theory,* then we may say that we have succeeded in accomplishing at one and the same time the following things:



Measurements of the Distribution of Particles

A droplet of the emulsion is placed in a container having a depth of about one-tenth of a millimeter and covered by a slide. The drop can be examined vertically in order to obtain a view of the ensemble, and horizontally in order to observe in detail the movements of the grains of a given section.

1. We have imparted a considerable and even unlimited degree of credibility to the molecular theory.

2. We have recognized the precise correctness of the explanation of the Brownian movement.

3. We have obtained an experimental determination of the number of Avogadro and consequently of molecular magnitude.

M. Jean Perrin has succeeded in obtaining this result in various ways.

In the first place it is necessary to obtain precisely identical granules in the same emulsion. Perrin succeeded in doing this by a fractional centrifugation of emulsions of gamboge or of mastic. The operation requires patience—for example, in one of the most careful fractionizations it was necessary to treat 1,200 grams of gamboge in order to obtain at the end of several months a few grams of emulsion in which all the grains were of the same size. The granules were spherical; it was necessary to know their diameter and their density. Precise measurements have been made by several processes. In the majority of the experiments the diameter of the granules was not more than a few ten-millionths of a millimeter.

Contents of One Cubic Centimeter of Argon Gas

The molecules, which are inconceivably small, are, on the other hand, so numerous, that if those in one cubic centimeter of argon could be placed end to end they would encircle the earth 200 times.

The determination of the number of Avogadra has been made by four different methods, to-wit:

First method: *Study of Displacement of Translation.*—The observer follows a grain in the field of the microscope and notes its position at equal intervals of time. If we know the dimensions of a grain, the viscosity of the liquid in which it is suspended, and the average of the squares of the trajectories traversed in equal intervals of time, we are able, by means of formulas which we owe to M. Einstein, to calculate the average live force and consequently the number of Avogadro.

Second method: *Study of Rotations.*—The grains revolve upon themselves; if they are comparatively large (a twentieth of a millimeter), we are able, thanks to visible internal inclusions which give us measuring points, to measure at equal intervals of time the angles at which they have revolved. The same formulas of Einstein likewise enable us to derive from these measurements the average energy of rotation (which is equal to the average live force of translation).

Third method: *Measure of the Speed of Diffusion.*—That is, of the rate of speed at which the grains held in suspension distribute themselves in a portion of the liquid which originally did not contain them.

Fourth method: *Study of the Distribution in Altitude of the Grains.*—We know that the gases which compose the atmosphere of the earth become increasingly rarefied in proportion as we ascend from the surface of the earth. The force of gravity which attracts the molecules toward the ground is counterbalanced by the tendency inherent in gases to distribute themselves through space; it is this diffusion of gases which prevents them from accumulating totally upon the surface of the earth. *The law of the distribution of gaseous molecules is very simple: equal rarifications correspond to equal altitudes.*

Let us imagine an atmosphere composed of a pure gas, oxygen, for example, at the ordinary temperature. Every time that we ascend for a distance of five kilometers, starting from no matter what altitude, we should find the pressure only half as great. But if the supposed atmosphere were of hydrogen, which is only one-sixteenth as heavy as oxygen, it would require an ascension of $16 \times 5 = 80$ km. to obtain a pressure one-half as great. The heavier the gas the more rapid the rarefaction, and the ratio of the altitudes to which it is necessary to ascend in the two gases respectively to obtain the same degree of rarefaction is the inverse of the ratio of the weights of the molecules of these gases—which is quite logical.

The terrestrial atmosphere is composed of a large number of gases; each of these possesses an atmosphere which is proper to itself independently of the others, so that the composition of the atmosphere varies with the altitude. At the surface of the globe there is scarcely any hydrogen in the air; at 100 km. of altitude there is still less (a little less than half); however, this small amount of hydrogen forms at an altitude of 100 km. 99/100 of the gases which one would find were one capable of ascending to such an altitude, by reason of the fact that the other gases are rarefied much more rapidly.

If the granules of an emulsion follow the laws of gases they must distribute themselves in function of their altitude according to the same law, but the rarefaction must be enormously rapid. By applying the law which has just been indicated the ratio of the altitude to which it is necessary to ascend in a gas and in an emulsion in order to obtain the same degree of rarefaction, is the inverse of the ratio between the weight of the molecule of the gas and the apparent weight of a granule (we are here concerned with the apparent weight, the difference between the weight of the granule and an equal volume of the liquid in which it is suspended, since the granule is subject to the thrust of the liquid). We have, therefore, by the measurement of the rarefaction corresponding to a known difference of level in the emulsion, the means of comparing directly the weight of an immaterial gaseous molecule with the known weight of a material granule.

In order to measure the rarefaction we proceed in the following manner: the microscope being focused upon a horizontal section of the emulsion, we limit the visual field of the apparatus in such a manner that there shall appear at the same time only a very small number of granules—a number which can be estimated correctly by a single glance of the eye. We note the number of granules perceived simultaneously at equal intervals of time and we make a very large number of observations in this manner—200 for example—and then add all the figures. We thus obtain a first total. We next place under observation another section of the emulsion at a different level—the difference in altitude from that of the section previously observed being meas-

ured by means of the vertical displacement given to the microscope—and we then repeat the same operations precisely, with the same number of observations, at the same intervals of time. We then obtain a new total by adding all these figures. The ratio between the two totals gives the ratio of the concentration at the two levels. Knowing the volume of a granule, its density, and the density of the liquid, we possess all the data required for the comparison with a gas and the determination of the number of Avogadro.

M. Perrin has obtained the following values for the number of Avogadro:

68.8 10^{22}, or 688 thousand billions of billions, according to the scientific method of the displacements of translation; 65 10^{22}, according to that of rotations; 69 10^{22}, according to that of diffusion; and finally, 68.2 10^{22}, according to the method of distribution by altitude.

As M. Perrin points out, the domain of the verification of the laws of gases is quite considerable when we remember that the nature of the grains has varied, that the nature of the liquid has varied, that the temperature has varied (from minus 9°C. to plus 58°C.) that the apparent density of the grains has varied within wide limits, that the mass of the grains has varied in the ratio of 1 to 70,000 and finally, that their volume has varied in the ratio of 1 to 90,000.

It is evidently not by chance that we have obtained for the number of Avogadro figures so close to the figure predicted by the theory of gases (we have indicated 63 10^{22}) under the most varied conditions of experiment. The beautiful experiments performed by Perrin furnish one of the best proofs of the objective reality of molecules; by these experiments molecular movement is almost made visible, since the Brownian movement is a faithful image of it upon a large scale. There are still other prenomena which have led to the determination of molecular magnitudes.

I should like to say a few words also concerning the irregular distribution of molecules, or *fluctuations.*

Let us consider a very small volume of gas: by reason of the perpetual agitation of the molecules the number of these contained in this small volume is constantly variable; it undergoes fluctuations.[4] The average value of the fluctuations depends upon the volume under consideration and upon the average number of molecules contained therein; this value, therefore, bears a relation to the number of Avogadro. It results from these fluctuations that a luminous pencil of rays traversing the gas is diffused. Everyone has seen a ray of sunlight made visible by the dust suspended in the air; this dust diffuses the light. In the same manner any lack of homogeneity in a medium renders this medium disturbed and produces a lateral diffusion of the light. Since the fluctuations in gases involve a lack of homogeneity they necessarily occasion the diffusion of a ray of light.

The proportion of light diffused depends upon the color of pencil of rays emanating from the luminous source. In the case of a pencil of white light coming from the sun (white light being formed, as we know, from the superposition of all the colors which one sees separated in the rainbow) there is an unequal diffusion of the different colors and it has been demonstrated that the result is a strong predominance of the blue. This is the explanation of the blue color of the sky, which results from the hetrogeneous character which the fluctuation in the distribution of the molecule imparts to the atmosphere.

If this hypothesis is correct the measurement of the ratio between the intensity of the light received directly from the sun and the intensity of the light coming from a point in the sky at right angles to the sun will enable us to calculate the number of Avogadro. MM. Bauer and Moulin have performed this experiment and have obtained 60 10^{22}; it would be superfluous to remark upon the beauty of this result which gives us one proof the more of the reality of molecules, and at the same time reveals the origin of the blue color of the sky.

In the same order of ideas the study of the opalescence of vapors in the vicinity of the temperature which we call the critical temperature has enabled MM. Kamerlingh Onnes and Keesom to determine the number of Avogadro in still another fashion. The result obtained by them was 75 10^{22}.

The *phenomena of radio-activity* have led to the determination of the number of Avogadro in various manners. I will indicate one of these processes. We know that radio-active bodies undergo a spontaneous transformation, at the same time giving birth to a successive series of elements whose atoms have a more or less ephemeral life.[5] These transformations are frequently accompanied by an emission of rays called *alpha rays;* it has been demonstrated that the alpha rays are formed of a flux of electrified particles animated by a very great degree of rapidity (attaining a speed of 20,000 km. per second). Experiments which I am unable here to describe have led to the belief that the *alpha* particle is an atom of helium; moreover, it is known that the emission of *alpha* rays is always accompanied by the production of helium.

By means of direct measurements it has been possible to count the *alpha* particles emitted in a given time by a given quantity of a radio-active body, such as radium, for example (Rutherford and Royds, Regener); among the methods employed I will cite the observation of the scintillation of a phosphorescent screen, each scintillation making the arrest of an *alpha* projectile: in this experiment the atoms have been made individually perceptible by the effect of the bombardment, each of them producing a minute luminous flash upon the screen.

We know, therefore, the total number of *alpha* particles emitted in a second by a gram of radium; this number is enormous: 136 billions per second, which amounts in a year to $136 \times 86{,}400 \times 365$ billions of atoms (or of molecules, since helium is mono-atomic). It has been possible, furthermore, by collecting the helium engendered by a known quantity of radium, to measure directly the quantity of helium produced in a year, which has been found to be 156 cubic millimeters.

Therefore this amount of helium ought to contain $136 \times 86{,}400 \times 365$ billions of molecules, which is done in the volume of the molecule-gram (22,400 cubic centimeters) 62 10^{22} molecules, a number very close to that obtained by the study of the Brownian movement. A similar determination, made with the helium disengaged by polonium, has given 65 10^{22} (Mme. Curie and M. Debierne).

I can do nothing better, in closing, than to reproduce Perrin's table, showing the convergence of the determinations of the number of Avogadro. Not only is it true that one always finds, by each method, the same value, though varying the conditions of the experiment within the widest limits, but, furthermore, phenomena which, *a priori*, appeared to bear no relation to each other, give almost exactly the same figures. Thus there is evidently a connection between these phenomena, and this bond must inevitably be the actual existence of molecules.

Phenomena Observed		N / 10^{22}
Kinetic theory, viscosity of gases		62
Brownian movement	Distribution of grains	68.3
	Displacements	68.8
	Rotations	65
	Diffusion	69
Fluctuations	Critical opalescence	75
	Blue of sky	cc. 60
Spectrum of black body		64
Charges of spherules (in a gas)		68
Radioactivity	Charges projected	62.5
	Helium engendered	62 to 65
	Radium disappeared	71
	Radiated energy	60

[4] The exact definition of the fluctuation is $\frac{n-n_0}{n_0}$, in which case n_0 represents the number of molecules which the volume would contain if the concentration were strictly uniform, while n represents the number contained by chance at a given instant. The average value is $\sqrt{\frac{2}{\pi}\frac{1}{n_0}}$, the smaller the volume the greater being the average value.

[5] *Vide* the article by M. Jean Becquerel entitled: *La Radio-Activité de la Matière* in *La Science et la Vie*, Feb., 1914.

The Influence of the Six-Hour Day on Industrial Efficiency and Fatigue.

Lord Leverhulme suggests that, instead of the usual eight-hour shift system, in which, as a rule, the machinery is running only forty-four hours a week, the workers should be put on two six-hour shifts every day, viz., from 7 a. m. to 1.30 p. m., and 1.30 p. m. to 10 p. m. with half-hour breaks for meals By this means the machinery would be kept running for seventy-two hours per week, and, as the overhead charges for machinery are often higher than the cost of wages, it would still be possible to pay the workers as much for six hours' work as for eight hours' work, even if their rate of production did not improve in consequence of the shorter hours.

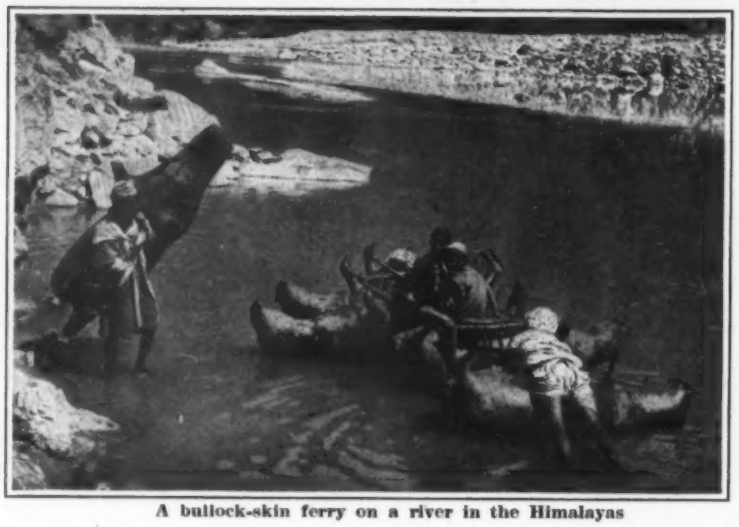
The available evidence does not indicate that there would be much improvement of output in many industries. In the tinplate trade the millmen sometimes work eight-hour shifts, and sometimes six-hour shifts, and their hourly output was found to be only 10 per cent. greater in the latter instance than in the former. In the iron and steel industry a reduction of shift from twelve to eight hours caused no increase of hourly output from blast furnaces and rolling mills, but 2 to 9 per cent. increase from openhearth steel furnaces. In the cotton-spinning mills of the United States a reduction of two or three hours in the weekly hours of work caused an almost proportional decrease of output. However, very different results were observed in certain munition industries. Men engaged in the somewhat heavy operation of sizing fuse bodies increased their hourly output 39 per cent. when their nominal hours were reduced from sixty-seven to fifty-six per week, and their actual hours of work from 58.2 per week to 50.6 per week, or their total weekly output went up 21 per cent. Women engaged in turning aluminum fuse bodies on capstan latres improved their hourly output 56 per cent., and their total weekly output 15 per cent., when their hours of actual work were reduced from 66.0 per week to 48.6 per week. The reason why reduction of hours causes such different effects in different industries is because of the various degrees to which the work is controlled by the personal element, and by machinery. In sizing fuse bodies, the men are not dependent on any machinery whatever, and can speed up to any extent they wish. In turning fuse bodies, the women are to some extent limited by the speed of the machinery. In another operation known as boring top caps, the youths emplpoyed fed the caps into semi-automatic machines which could not be speeded up. Consequently their output could only be improved by their keeping more closely to their work, and it was found that when their hours of actual work were reduced from 72.7 per week to 53.1 per week, their hourly output increased only 27 per cent., or was insufficient to balance the reduction of hours, and in consequence their total weekly output fell off 7 per cent.

It is probable that in most industries the eight-hour day does not cause more than a moderate amount of physical fatigue. The workers suffer rather from monotony and boredom, as many of them are engaged in the same task day after day, and year after year. Especially on these grounds it is to be hoped that some such scheme as Lord Leverhulme's will gradually be adopted in the industrial world, but it cannot come suddenly, as it might render us unable to compete in the open markets of the world with other countries which adopted, for instance, two seven-and-a-half-hour shifts per day, instead of two six-hour shifts.

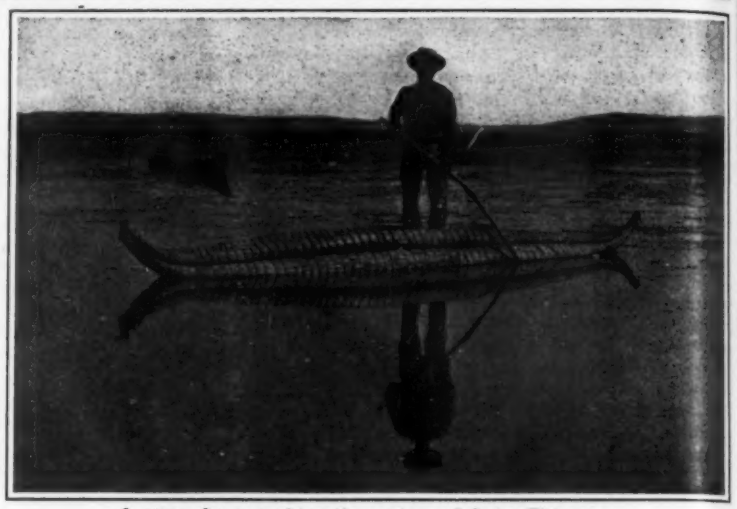
Lord Leverhulme suggests that, in addition to six hours' factory labor, the workers should spend two hours daily in educational and physical training. There is much to be said for this plan.—(Abstract of a paper read before the Physiological Section of the British Association by H. M. Vernon, M.D.)

"Storms of Cold" and Their Paths.

Thunderstorms are usually divided into two classes (a) heat storms and (b) storms in depressions. The former are usually local in character, the latter accompany line-squalls which are experienced in the southern sectors of depressions. The author describes a third type of thunderstorm, namely, "storm of cold," which occurs in a cold zone of air advancing from the north into a region where temperature is high, and upper winds are from the south. In these circumstances cumulonimbus clouds developing into thunderstorms are formed on the southern boundary of the cold wave, and are carried northwards by the upper south wind in a direction opposite to that of the north wind at the surface. Thus the storms travel backwards through the zone of cold air.—From *Comptes Rendus* (*Science Abstracts.*)



A bullock-skin ferry on a river in the Himalayas



A straw boat used on the waters of Lake Titicaca

Some Odd Modes of Travel

Peculiar Conveyances for Land and Water Transportation

By James M. Treadwell

Photographs Copyrighted Publishers Photo Service

THE transportation facilities of a country are an index of its progress. Without adequate means of rapid transit for the conveyance of goods and information a country is bound to become segregated into more or less isolated communities which, for the lack of the broadening influences of association with fellow communities, becomes dwarfed and intellectually stunted. Our civilization has been built up by means of our railways, steamships and motor vehicles; and we are now launching into aerial transportation. To this list should be added the telegraph and telephone, also radio communication, which should properly be included in the broad classification of transportation, because they furnish the means of carrying information and ideas between remote stations. The airplane and dirigible on the one hand, and radio communication on the other, have got us past the limitation of roadways and fixed lines of wire. We have reached, or are just about to reach, the highest development of complete and rapid transportation, and from this viewpoint it is interesting to look about us and study the situations in primitive lands.

The means of transportation that have been adopted by savage and uncivilized peoples are not to be looked upon with scorn. A careful consideration of them shows that they are peculiarly adapted to the handicaps with which the people have to contend. Where there are no roads, rivers usually furnish the best means of communication and there is no end to the varieties of boats that have been constructed by the various peoples of the earth. An interesting type of boat is shown in one of the accompanying photographs. It is built of straw, which is about the last material one would expect to prove serviceable for the construction of a vessel of any kind. The Indians of Bolivia make a sort of canoe out of very closely woven straw and with it navigate the waters of Lake Titicaca.

In another corner of the earth, also up among the mountains, a very different type of boat is used. The natives of the Himalayas use the inflated skins of bullocks. One skin will easily support a man and by tying several together and mounting a wooden frame upon them, a boat is built on which a number of people can ride. The photograph which is here reproduced was taken on the Sutlej River in the Himalayas, where a ferry service is carried on across the river by means of these peculiar pneumatic boats.

One would hardly expect to find sleighs in use in the Island of Madeira. It lies off the coast of Northern Africa and naturally never sees any snow. Nevertheless, sleighs are to be found there, and in place of the swift and graceful reindeer they are drawn by the slow, clumsy ox. The streets of Madeira are paved with smooth round stones, and over these stones the runners of the sleighs travel quite freely. In fact, the motion of the sleigh is much smoother than would be that of a wheeled vehicle, because the runners readily pass over small depressions in the pavement without jar. At the extreme left of the picture may be seen a sledge adapted to carry freight. The passenger sleigh is much more elaborate, with its upholstered seats and figured curtains to protect the occupants from the weather as well as from the gaze of the curious. The body is mounted on springs, and it is said that riding in one of these primitive vehicles is very pleasant, albeit rather slow for one of Yankee temperament.

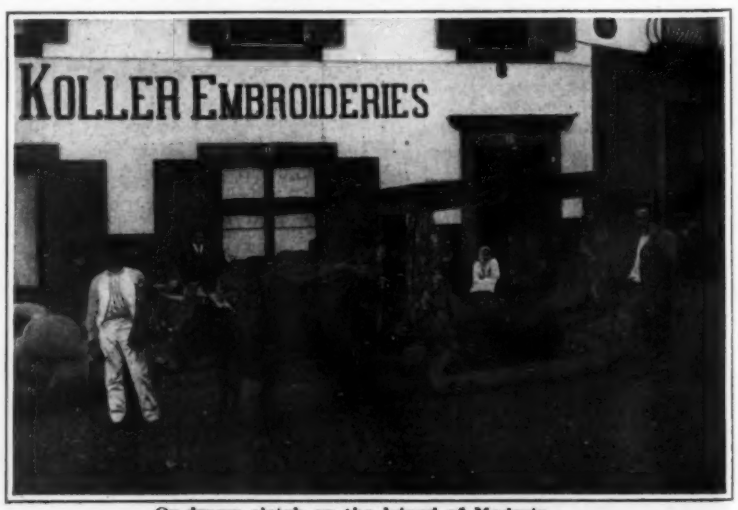
In Egypt the camel holds sway, and it is peculiarly adapted for travel over the sandy wastes of that country. As wheeled vehicles cannot be operated satisfactorily in sandy regions, because the wheels will sink deeply into the loose sand, the natives have developed a car which is carried tandem-fashion by two camels. The native Egyptian lady must never show her face to the male folks except her husband When the women go on the street they are veiled so as to hide their face. Those of the upper class do not walk, but ride on a car such as shown in the photograph. The car, which is richly decorated, is provided with shutters that are here shown open, but when the car is occupied these are always closed. The shutters are so arranged that the ladies may look out and see what is going on, although they cannot be seen from the outside. Scant consideration is given to the poor beast at the rear. His proud head is humbled and fastened under the car so as to keep his inquisitive nose from poking through the windows.

In South America we have the diminutive cousin of the camel: the llama is the beast of burden of the Andes. It is a very sure-footed animal and is well adapted for travel over the trails of the mountains. Llamas are used for carrying copper in the mining regions of Peru and Bolivia. Each animal carries a load of one hundred pounds and no more: if the beast is overburdened he will simply lie down and cannot be moved. In this respect he is said to be even more stubborn than the southern mule.

The frontispiece shows a peculiar mode of travel in China. We usually think of the jinricksha as a Japanese vehicle, but it is also to be found in China, and in this instance particular interest attaches to the runner who hauls the two-wheeled conveyance. This human substitute for a horse is clad in a cheap but very efficient rainproof coat. It is a coat made of grass, from which the water runs off readily. The speed and endurance of these human horses are remarkable.

These are but a few illustrations picked at random from the many interesting modes of travel to be found in remote corners of the earth, and in considering them one cannot help but be impressed with the resourcefulness of the natives who have developed them.

An elaborate lady's car in Egypt



Ox-drawn sleigh on the Island of Madeira

Sex in Eggs and Chickens

Some Strange Theories Regarding This Baffling Problem

By Mickael K. Boyer

THE sex of eggs cannot be foretold before they are hatched, and then not until the chickens have sufficiently matured so that they may show characteristics of their sex. We are told in history that Aristotle, 350 years B. C., discussed the problem; that Pliny, the elder, advanced theories on it, while Columella, in one of his books, deals extensively with the subject. In what is known as Columella's Eighth Book he says: "The best time to set a hen is when the moon is increasing, from the 10th to the 15th of the month. If all males are desired, set only pointed eggs; if all females, set the rounded ones."

Bradshaw says that although the above would scarcely now be accepted as orthodox, still Columella advocated methods of management that are more or less adopted at the present time.

From the time of these early writers down to our present period, nearly every naturalist has in some way touched on the subject, while the majority of bird specialists have offered opinions. With some of these writers theories give place to dogma, the contour of the egg, or other circumstances, being the only warrant for their predictions as to the sex of the unborn chick. Eggs long and thin have been described as those which will produce cockerels; the short, dumpy ones, pullets. There are even some writers who go so far as to say that eggs produced before noon are responsible for a certain sex, while those laid in the afternoon are of the opposite gender.

Bradshaw tells another theory, which had votaries—that a new-laid egg would hatch out a cockerel, but that if not placed under the hen until the fourth or fifth day, it would change to a pullet. Still another idea was connected with the position of the eggs in the nest. Should it happen that the end point south, it meant a pullet; but if north, a cockerel. There were still other methods of discovering sex that were advocated, even to the extent of using X-rays and other media.

The Agricultural Gazette of New South Wales says all former theories and opinions, however, paled into insignificance in March 1909, when at the invitation of a Mr. Williams the editors of several English poultry journals—W. T. Stead and others—met at the Hotel Cecil, in London, to witness a demonstration of the work of a little instrument that, by its action could, it was claimed, foretell the sex of any animal; that it could accurately tell the sex of the chicken in the egg, and also whether the egg was fertile or not.

"The instrument was simply a small pith ball suspended at the end of a magnetized steel or copper wire, with a handle at the other end. The instrument was held over rabbits, mice, fowls, etc., and when held over a male animal the ball rotated steadily, but when placed over a female it swung backward and forward—pendulum fashion."

The same motions were produced over some eggs, and over others the ball would not move. The latter were said to be infertile. This created quite a commotion among the poultrymen, but many breeders described the claim as absurd. Later on, one of the poultry papers published a letter from a correspondent who wrote that the motions of the pith ball over an egg and like results could be had with a darning needle attached to a silk thread.

Another writer said it is surprising what an amount of credulity exists in the world. Any student of embryology will tell that for the first few days the chicken in embryo is asexual, and on the seventh day distinctly hermaphroditic—containing within itself elementary organs pertaining to both sexes. After this stage it verges in one direction or another, one set of organs diminishing as the other increases. It will be seen that the merest accident determines the future of the bird, the nutritive values obtainable from the pabulum reacting constitutionally or otherwise on the growing organs of sex. Thus, since the germ of life can have no sexual attributes, it is obvious that the pendulum theory falls to the ground.

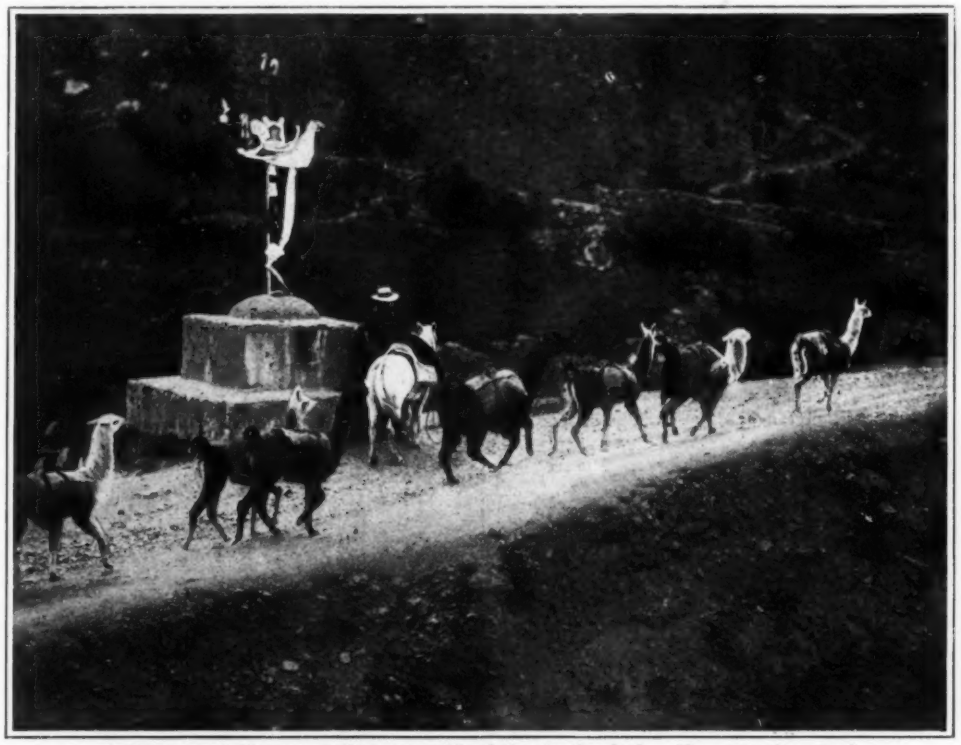
When once we are able to determine from outward demonstrations prior to birth what is the sex of the mare's coming foal, the cow's approaching calf, the ewe's maturing lamb, we may be able, possibly, to guess what the sex of the chicken is in the unhatched egg. This is one of the "secrets" which we opine will forever remain unrevealed to the most ardent experimentalist in our humble profession. All we can ever know, as to whether an egg will produce a male or a female, we shall ascertain satisfactorily when the bird bursts its little shell-prison and reveals the fact as it develops.

In 1864, John Nicholson Navin, in his book on Veterinary Practice, said that a Mr. Newall, of Philadelphia, selected 200 rooster-eggs and when they hatched there was but one pullet, and he was sure the egg producing it was a fraud. He also selected 50 pullet eggs which hatched 50 pullets. He said the pullet eggs are smooth on the ends, while the rooster eggs have a zig zag mark or quirl on one end.

Professor Thomas Shaw, in his work on Animal Breeding, says there is a theory that every alternate egg or germ produced by the female is of the same sex. According to this theory, therefore, the sex of the offspring will depend upon the egg or ovum impregnated. The fallacy of this theory is pointed out by Professor Shaw, who says that it is also in conflict with the observed influence of nutrition on the sex of certain insects and plants.

Professor Shaw concludes, after reciting seven prominent theories: "Mainly in the controlling or determining of sex in animals, that up to the present time, it would be correct to say, all these theories have, in the main, if not entirely, eluded the grasp of the most patient investigators. Notwithstanding the immense amount of research given to the study of this question and the much experimenting done regarding it, the little progress that has been made in the inquiry thus conducted is humiliating."

What Professor Shaw says of the theories in the animal kingdom will hold good in henology. It is impossible to determine the sex of the egg before incubation, or the sex of the chicken before it has sufficiently developed to show its standing in this world.—(From *American Poultry Advocate.*)



A Caravan of Llamas passing a wayside shrine in the Andes (See opposite page)

The Value of Lupins in the Cultivation of Poor, Light Land.

Lupins grow with remarkable luxuriance on very light land, poor in lime. At the present time, owing to economic conditions, there is grave danger that considerable areas of this type of land will go out of cultivation. It would appear that an extended growth of lupins offers one of the simplest methods of rendering economically possible the cultivation of this land, and possibly of reclaiming what is already derelict.

Owing to their deep-rooting habit, and their powers of assimilating the free nitrogen of the air, lupins greatly enrich the soil, and whether ploughed in green, folded with sheep, or harvested for seed, leave a considerable quantity of residue upon the ground, which is of great value to the succeeding crop. Very heavy crops of rye are being grown this year after lupins on land actually adjoining the heath.

When folding, care must be taken not to allow the sheep to eat too much or they will suffer from paralysis owing to lupin poisoning. Suffolk flockmasters fold their sheep on lupins with confidence, and do not regard the risk as serious. Sheep take some time to get accustomed to the bitter flavor of lupins, but thrive remarkably well once they have become used to them. They cannot live satisfactorily on lupins alone, but must have access to other food.

There is often some difficulty in disposing of lupin seed, owing to the fact that it contains some poisonous substance, and is very bitter. In Suffolk lupin grain is fed to sheep at a rate not exceeding half-a-bushel per day per 100 sheep, and the feeding must commence gradually. If too much is fed the sheep become paralyzed. It is claimed in Holland that a method has been dicovered whereby the poisonous principle can be extracted, and the grain rendered fit for stock-feeding purposes. If this could be done it would give a great stimulus to lupin-growing, and would be a considerable advantage to light-land farmers, as lupins might then occupy the same place on light land as is occupied by beans on heavy land.—(Abstract of a paper read before the Agricultural Section of the British Association by A. W. Oldershaw, M.B.E., B.Sc.

The Welding of Glasses.

Writing in *Nature* (London), L. Appert discusses the welding of glasses and enamels with one another and with metals, with reference to athermancy and diathermancy, inalterability and neutrality, first on historical lines. There is no mention of special experiments, nor are there any literature references. He concludes that all glasses of different compositions can be completely and permanently welded and that the limits within which the relative proportions may be varied are very narrow; with regard to thermancy a standard of known composition should be used; neutrality should be tested with the blowpipe. In the case of enamels the mordant should have the same dilatation coefficient from the outset and the enamel be applied in very thin layers.—(*Science Abstracts.*)

The Physiology of Sneezing*

Discussion of the Causes and Effects of Such Spasmodic Expirations

By A. P. Brubaker, M.D., Philadelphia

Sneezing may be defined as a spasmodic expiration preceded by one or more spasmodic inspirations. The expiration is momentarily opposed by the closure of the nasopharynx and a more or less complete closure of the mouth. With the onset of the expiration there is a rapid rise of intrapulmonic pressure which, when a certain value is attained, suddenly forces open the nasopharyngeal partition. In consequence, a blast of air is driven into and through the nasal chambers; at the same time, however, the mouth, not infrequently, is partially opened, thus permitting a portion of the blast to be driven through the buccal orifice. The object of the sneezing spasm is the dislodgment of mucus or other fluid from the surface of the nasal mucous membrane.

The act of sneezing is, in its entirety, quite complex, and may be subdivided for convenience of presentation into two phases, a nasal and a respiratory, both of which are reflex in character and involve two different reflex mechanisms, a nasal and a respiratory. Each mechanism consists of afferent nerves, a central mechanism, effected nerves and responsive organs.

THE RESPIRATORY SNEEZE.

As the effective portion of the sneeze is the respiratory, it will be conducive to clearness if this is considered first.

The primary activity in this reflex is a deep inspiration or an enlargement of the thorax and lungs, which has as a result the inhalation and temporary storage of a large volume of air, a condition essential to the satisfactory accomplishment of the object of the sneeze. The inspiration is an active process and is accomplished by the simultaneous and coördinate contraction of various groups of muscles, among which, as representatives, may be mentioned the posterior crico-arytenoids, the diaphragm and the external intercostals. The coördinate action of the three groups of muscles implies the coördinate activity of three groups of nerve centers and their related nerves; thus the activity of the posterior crico-arytenoids is called forth by the discharge of energy from the laryngeal center in the medulla oblongata, and transmitted by efferent fibers in the trunk of the vagus and their continuation in the inferior or recurrent largyngeal; the activity of the diaphragm and the external intercostals is called forth by the discharge of energy from the phrenic and intercostal centers in the cervical and thoracic segments of the spinal cord, respectively, and transmitted by the phrenic and intercostal nerves.

The coördinate contraction of the different inspiratory muscles implies a practically simultaneous discharge of nerve energy from each of the foregoing nerve centers; and this in turn necessitates the existence in the central nerve system of a single group of cells from which nerve impulses are discharged and transmitted by its axonic processes to the laryngeal, phrenic and intercostal nerve centers in the medulla oblongata and the spinal cord, and by which they in turn are excited to and coördinated in their activity. To this group of cells the term "inspiratory center" has been given.

Though the activity of the inspiratory center is normally regulated by nerve impulses ascending the vagus nerves from the lungs, nevertheless it is capable of stimulation in a more or less abnormal manner by the arrival of nerve impulses through other afferent nerves coming from different regions of the body.

The secondary activity in this reflex is a forcible expiration, or a diminution in the size of the thorax and the lungs, which has as a result a compression and expulsion of the previously stored volume of air. Though expiration is normally a passive process and accomplished by the recoil of the elastic forces of the thorax only, under the conditions characteristic of sneezing, these forces are reinforced by the coördinate contraction of various groups of muscles, among which, as representatives, may be mentioned the internal intercostals and the abdominal muscles.

The coördinate action of these groups of muscles likewise implies the coördinate activity of groups of nerve centers and their related nerves. Thus, the activity of the internal intercostals is called forth by the discharge of energy from nerve centers in the thoracic segments of the spinal cord and is transmitted by the intercostal nerves; the activity of the abdominal muscles is called forth by nerve energy discharged from the lower thoracic and perhaps upper lumbar, segments, and is transmitted by the lower thoracic and the iliohypogastric nerves.

The coördinate contraction of the expiratory muscles implies a practical simultaneous discharge of nerve energy from each of the foregoing nerve centers; and this, in turn, necessitates the existence in the central nerve system of a single group of cells from which nerve impulses are discharged and transmitted by its axonic processes to the intercostal centers in the spinal cord, and by which they in turn are excited and coördinated in their activity. To this group of cells the term "expiratory center" has been given.

As to the manner in which the expiratory center is stimulated, if at all, under normal conditions of respiration, there is not much definite information available. But as a forced expiration always involves a volitional effort or a discharge and transmission of nerve energy from the cerebrum to the expiratory center, it may be conceived that under the conditions of the respiratory apparatus peculiar to sneezing, the expiratory center is aroused to activity by the descent of nerve impulses from the cerebrum.

Just preceding and conditioning the forcible expiratory effort, the respiratory passage is shut off from the nasal cavities by a partition formed by the elevation of the palate, the advance of the posterior half arches, and the contraction of the superior constrictor of the pharynx. This coöperative muscle contraction results from the discharge of energy from the cells of origin to the spinal accessory nerves.

At this moment the intrapulmonic air is compressed on all sides by the descent of the ribs, the result of the contraction of the internal intercostal muscles, and by the upward movement of the abdominal viscera, the result of the contraction of the abdominal muscles. With the rise of the intrapulmonic pressure, there comes a moment when the nasopharyngeal partition is forcibly separated, and the air is driven into and through the nasal chambers with a more or less complete dislodgment of the mucus.

The afferent portion of the nerve mechanism, by which the inspiratory reflex is occasioned, consists of fibers of the trigeminal nerve, the peripheral terminations of which are distributed to the nasal mucous membrane, and the central terminations related histologically and physiologically to the inspiratory center.

The stimulus adequate to the excitation of these peripheral nerve endings is a dilation of nasal blood vessels and the discharge of clear, slightly viscid secretion, perhaps specific in character, from the glands embedded in some portion of the nasal mucous membrane. When this secretion is discharged, and begins to trickle over the terminals of the nerve endings in certain regions, nerve impulses are developed which, transmitted to the inspiratory center, stimulate it and cause it suddenly to discharge energy to the spinal inspiratory centers and muscles. With this, the effective portion of the sneezing mechanism is excited and coördinated in activity.

Coincidentally with the stimulation of the afferent nerve fibers of this reflex mechanism, there occurs simultaneously a stimulation of purely sensory nerves. The nerve impulses developed in them are transmitted to sensory areas in the cortex of the cerebrum, where they evoke sensations of a peculiar trickling or quivering character which contribute much to the pleasure of the sneeze, and at the same time lead to various muscle reactions and sounds of a more or less pronounced character.

THE NASAL PHASE.

As stated in a previous paragraph, the stimulus adequate to the excitation of the sneezing mechanism is the production and discharge of a secretion from glands in the nasal mucous membrane. The production of this secretion is also a reflex act and involves a nerve mechanism consisting of afferent nerves, central cells, efferent nerves and their related responsive organs, glands and blood vessels. Collectively their physiologic action constitutes the nasal phase of sneezing.

The production of the stimulating secretion requires the coöperation of blood vessels and gland epithelium, both of which require for the manifestation of their activity the stimulating influence of nerve energy originating in the central nerve system and transmitted to them by the afferent nerves of the reflex mechanism.

The nerves distributed to these structures belong to the autonomic system, and therefore consist of two consecutively arranged and histologically related neurons known as preganglionic and postganglionic.

In a consideration of this mechanism it will be convenient to consider the postganglionic neurons first. The cell bodies of these neurons are found in, and compose in large part, the sphenopalatine ganglion. From these cells axonic processes pass forward to become histologically related to the walls of the blood vessels and the epithelium of the nasal glands, from which it may be inferred that the sphenopolatine cells are related to vasomotor and secretion or phenomena. The sphenopalatine cells, however, do not possess spontaneity of action, but require for their excitation the arrival of nerve energy, originating in cells in the central nerve system and transmitted to them by their preganglionic axons. These cells, which constitute the central part of this reflex mechanism, are located in the gray matter beneath the floor of the fourth ventricle. The axonic processes to which they give rise pass forward and emerge from the medulla in the nerve of Wrisberg, of which they constitute a large part; they then pass into the sheath of the facial nerve; after a very short course they leave the facial nerve at the genu, and after that become the great petrosal nerve, the peripheral terminations of which arborize around the cells of the sphenopalatine ganglion.

There is thus established a pathway between the central nerve system and these local peripheral organs along which nerve impulses pass from the center to the periphery. That this is the case is shown by the results of experimentation; thus, if the great petrosal nerve in one of the higher mammals is divided and its peripheral end stimulated with induced electric current, there promptly occurs a dilation of the nasal blood vessels and a secretion from the nasal glands. Stimulation of the sphenopalatine ganglion has a similar result. From these facts it may be inferred that the nerve fibers composing the great petrosal nerve, as well as the cells from which they arise, are divisible into two groups, namely, vasodilatator and secretomotor. Any stimulation, therefore, of the central cells will be followed by vascular engorgement and the discharge of mucus.

The afferent portion of the mechanism is widely distributed, though it may be said to consist mainly of (1) cutaneous nerves, (2) nasal branches of the trigeminal, (3) visceral afferent nerves, and (4) nerves descending from the cerebrum.

The stimulation of certain cutaneous nerves, as is frequently the case when they are suddenly exposed to a low temperature or cooled by currents of air, will cause a dilation of the nasal blood vessels and a discharge of mucus, which in a short time will stimulate afferent nerve endings and occasion a series of reflex spasmodic sneezes. This stimulation holds true for the ankle, neck and head areas of the skin. The impulses thus peripherally generated are transmitted to the central vasodilatator and secretomotor cells, and excite them to activity.

Stimulation of the trigeminal nerve endings, chiefly in the nose, perhaps elsewhere, will cause the same vascular and secretory conditions, as is well known. The stimuli capable of exciting these nerve endings may be mechanical and chemical, as well as organic, emanations, of a more or less unknown nature, from animals and plants. Here, again, the primary effect of these stimuli is the production of the nasal mucus.

* Read before the Section on Laryngology, Otology and Rhinology at the Seventieth Annual Session of the American Medical Association, Atlantic City, N. J.

Stimulation of other sensor nerve endings, of the glossopharyngeal, the vagus, etc., has been observed to cause the same nasal phenomena, followed by more or less pronounced sneezing.

PSYCHIC STIMULATION.

Stimulation of vasomotor, secretomotor and visceromotor centers in the medulla oblongata and spinal cord, by nerve impulses descending from the cerebrum in consequence of psychic states of an affective or emotional character, is a well attested fact. It is only necessary to recall the effects of psychic states on the nerve centers regulating the vascular and secretory phenomena preceding the discharge of saliva and gastric juice; and on the nerve centers regulating the vasodilatator and the secretomotor phenomena of the sexual organs. Paralleling these effects are the effects of the psychic states on the vasodilatator and secretomotor phenomena of the nasal organs. It has, moreover, been frequently observed that the nasal and sexual phenomena often coexist, the two not standing, however in the relation of cause and effect, but as results of the same psychic state.

PATHOLOGIC CONDITIONS.

In this presentation the attention has been limited to the consideration of the normal or physiologic condition. This, if properly conceived, may assist in the interpretation of pathologic conditions. It is quite apparent that pathologic conditions might arise from an alteration in the way of an increase in the irritability of the afferent portion of the mechanism of the nasal phase of the reflex. Local pathologic states frequently so exalt the irritability of the nerve endings that a slight additional stimulation develops a greater number of nerve impulses than would otherwise be the case. As a result, the associated central cells are more profoundly stimulated and cause by their greater discharge of energy more pronounced peripheral effects. It not infrequently happens, also, that the nerve impulses thus developed are so numerous that they overflow their customary channels and stimulate vasodilatator, secretomotor and visceromotor centers in different levels of the medulla oblongata and the spinal cord, causing, in addition, the development of pathologic phenomena in the respiratory, the circulatory and other organs as well. Instability of the central mechanism, either in itself or as an expression of a more general nerve cell instability, the result of heredity or of dietetic or sexual excesses or other conditions, may lead to similar results.

Monistic and Dualistic Conceptions of the Stellar Universe—II

(*Concluded from our issue of September 27, No. 2282, page 203.*)

In any case, it may be wise to examine the facts showing the influence of these collisions of stars upon the distribution of their velocities.

4. And indeed, facts of this kind are not lacking. In the following table, from Gyllenberg, are given the semi-axes of the ellipsoids of velocity.

SEMI-AXES OF THE ELLIPSOIDS OF VELOCITY OF STARS OF DIFFERENT SPECTRAL TYPE

Color	Type	a_1	a_2	a_3	Ω
White stars	B & A	1.73	3.10	2.73	4.48
Yellow "	F & G	3.02	4.95	3.67	6,86
Red "	K & M	4.00	4.51	4.27	7.39

The figures represent siriometers per stellar year, the siriometer being equal to 10^8 astronomical units, and the stellar year being equal to 10^8 years. The axis a_1 is (approximately) directed to the center of the Milky Way; the axis a_2 is perpendicular to it in the Milky Way (toward the Vertex), and the axis a_3 is directed toward the pole of the Milky Way. Various researches made by Ludendorff, Shapley and others point to the conclusion that it is probable that the white stars have the greatest mass; next come the yellow, and the red ones have the smallest mass.

Considering all these points we find:

1. The mean velocities (Ω) of the stars are proportionally greater as the masses of the stars are small, which agrees with the law of equipartition of energy in the kinetic theory.

2. The largest axis a_2 is approximately perpendicular to the radius vector drawn from the center.

3. The other axes (a_1 and a_3) are, at least for the yellow and red stars, almost of equal length, so that the ellipsoid of velocity is a spheroid, located (almost) in the position necessary for dynamical equilibrium.

4. For the smallest stars (red) the three axes of the ellipsoid of velocity are almost of the same length, showing that these stars are already, at least approximately, in statistical equilibrium.

This seems to show that the "relaxation time" in a group of stars is proportional to the mass of the latter.

These considerations are, indeed, purely provisional, for a separation of spectral types here taken together (B & A, F & G, etc.), is necessary before one can undertake a conclusive discussion. (Thus the ellipsoids of velocity of B type stars differ essentially from those of A type stars.) In any case, the preceding considerations seem to indicate that the "relaxation time,' long as it may be, has already left some recognizable traces in the history of our stellar universe.

5. Eddington's Objections: Mr. Eddington, to whom we owe the most penetrating researches upon the subject of the two supposed star streams, gives in his book, "Stellar Movements and the Structure of the Universe" a complete criticism of the kinetic theory as applied to the stellar universe. This is his most direct argument. There are in the sky many systems of stars, traveling together in parallel orbits. Some show a great separation in space; for example, the well known system of Ursa Major, composed of the five stars of The Plough, (B, y, o, e, c) and of ten others scattered over a large part of the sky, the most interesting being Sirius.[1]

Certain of these systems have existed perhaps for a time comparable in length with the life of an average star. "They are traveling across a part of space where are scattered stars not belonging to their system. Nevertheless the equality of motion has not been seriously affected. It is scarcely possible not to conclude that the attractions due to accidental encounters of stars, in the neighborhood, have had no appreciable effect upon the stars' motion." Reasoning in this way, he concludes that "the apparent analogy with the kinetic theory is entirely out of the question," and that "the stars follow their paths under the influences of the general attraction of the stellar system without influencing one another."

One may say in reply to this argument that the stars which now belong to such a system are only the insignificant remains of a large cluster once constituting a very close system in space. Perhaps the stream of Ursa Major, consisting really of about a dozen stars, was made up, some millions or thousand millions of years ago, of a mass of millions of stars, of which the great majority have been scattered in all possible directions, due to the chance attractions of stars passing by in the neighborhood, leaving the most brilliant stars of The Plough[1] as a very poor reminder of its ancient wealth. Is not the relative rarity of stars in such systems indirect proof that the very great number of stars in the original mass have succumbed by the way to collisions with other stars, which encounters, though certainly rare and insignificant, yet in the course of time are capable of scattering the members of the same family of stars in all directions, just as surely as *gutta cavat lapidem non vi sed saepe cadendo?* If it were not a question of saying too much upon the subject, one might be tempted to offer as another proof of the action of these collisions, the fact that the stars belonging to these groups are generally white stars, or, at least, large stars, while the influence of collisions is felt more strongly in the case of the smallest stars, as we have seen in discussing the ellipsoid of velocity.

6. When one regards them in another light, the phenomena of systems of stars furnish another proof of the validity of the kinetic theory. Considering a group of stars—at first a globular cluster moving out into space, more or less filled with stars at rest or moving in parallel courses. The members of the cluster have from time to time to pass very near other stars, and each time they have to undergo a certain deviation and change of velocity. Is the nature of the cluster systematically changed by these encounters, and if that be the case, what form will the moving system take? Jeans studied this problem in 1916 and concluded that the members of the moving system, at first distributed spherically, will at length spread out in the form of a disc which will continue to spread as time goes on. The plane of the disc will be perpendicular to the line in which the cluster moves.

The conditions for the application of Jeans' results are not actually realized in the universe. The motion of a cluster is not rectilinear, nor of the stars either. We may suppose that the cluster is describing an elliptical orbit about the center of the universe in a period estimated as some thousands of stellar years. One can scarcely expect that, the orbital motion of the axis of the disc, into which the globular cluster is eventually changed, will remain parallel to the direction of motion; no more have we the right to consider that the ultimate form of the mass will be a disc. It is probable, not to push the analysis further, however, that the cluster will take the spheroidal form. It is quite remarkable that the only moving system which has at present been examined, shows this form.

Turner has shown that the system of Ursa Major has the form of a flat disc with diameter about eight siriometers and depth only about a half siriometer. We may, even if we do not have to, conclude that this cluster has had a lifetime equal to or greater than the "relaxation time,' and that these encounters with other stars have, during the millions of revolutions about the center of the Milky Way, transformed the original more or less condensed cluster into the thin flattened disc which we now see, while the principal part has been scattered into different parts of the universe.

7. Poincaré's Objection: We still have to consider one objection to the kinetic theory—an objection made by Poincaré in the article mentioned above. We have seen that one of the most important consequences of the kinetic theory is the law called the equipartition of energy, according to which the product of the mass by the square of velocity is a constant for all kinds of bodies in the universe. A direct consequence of this law is that the ultimate velocity of small bodies must be very great and infinitely great in the case of bodies whose mass is evanescent. The comets furnish some examples of such masses, and according to the kinetic theory we ought to expect their velocities to be infinitely great. But we know that the velocities of comets and of stars are of the same order. How do we explain this contradiction? Poincaré proposes to remove the difficulty by supposing that our system has not yet reached a stable state, which supposes that the comets have not yet attained their greatest velocities. The hypothesis upon which this rests—the hypothesis that any differentiation between the velocities of bodies of such different masses as comets and stars is not produced in the lifetime of our stellar universe—is evidently unsatisfactory and is in direct contradiction to the conclusion that the smaller stars, which have masses certainly millions of times greater than those of comets, have almost reached a stable state.

But there is another explanation which at the same time helps to settle an old and important cosmological question. According to the kinetic theory the comets ought to acquire, and have already acquired very great or even infinite speeds. Why do we not observe comets of this kind? We do not observe them because long ago they were expelled from the universe—just as the lightest gases have been expelled from the atmosphere of some of the planets. The only ones which have escaped this are the ones captured by stars. All comets which we can see must be members of the solar system, describing elliptical orbits about the sun. Such, indeed, is the direct consequence of the kinetic theory.

We may go farther. The comets are not the only bodies in the universe which are small (infinitely small). There are the meteors and the particles of meteoric dust. These must also in time—time already past perhaps—either be expelled from the universe forever, or be captured by suns and their planetary systems. It is here, perhaps, that we need to look for the explanation of the singular fact that extinction of light in space does not exist or is vanishing small. The ultimate state of our stellar system then is an assembly of stars moving according to Maxwell' law in a space free from comets, dust and other infinitesimal particles, which have all been concentrated about these suns, if they have not been absorbed by them or their planets.—*Lund Astronomical Observatory* (Sweden).

[1]The Plough—Charles Wain, Big Dipper.

Earth Effect on the Sun.—At Kodaikanal Observatory the spectrum of Venus has been photographed, in order to test whether a displacement of solar lines towards the red can be due to an earth-effect, since the said displacement varies with distance from the centre of the disc. The author considers that the results prove that the effect is not due, as suggested by G. T. Walker, to relatively, but thinks that it is probably due to the earth, though independent confirmation is still required.—*Science Abstracts* from *Nature*.

Petroleum Refining*

Instruments Used in Testing Oils

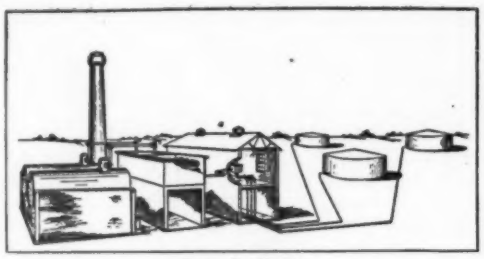
By R. W. Cunningham

From the original well on Oil Creek near Titusville, Pa., discovered by Col. Drake in 1859 the production of crude petroleum spread up into New York State and down through eastern Ohio into West Virginia and Kentucky; it also developed in Indiana and Illinois; then the Texas fields were discovered, then the Oklahoma, and now they are drilling in Kansas, while fields are outlined in Wyoming, South Dakota and California. For a long time Pennsylvania, Ohio, New York and West Virginia, known as the Appalachian Field, produced practically all the petroleum in the United States, but other fields have now outgrown it, and while today it is producing about 25,000,000 bbl. and Pennsylvania about 8,000,000, the big fields are in Oklahoma and California, with Kansas rapidly overtaking Oklahoma.

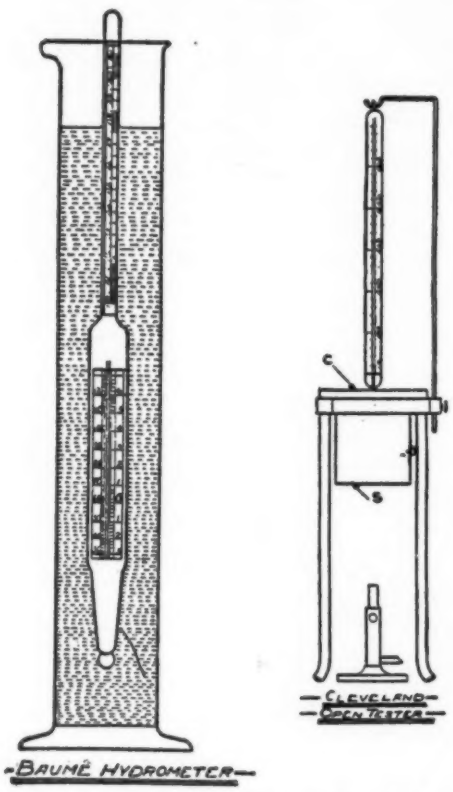
The uncertainty in the production of crude petroleum is well illustrated in the Cushing field, Oklahoma, which in 1914 was producing at the rate of 315,000 bbl. per day. In a very short time it dropped to 60,000 a month. However, the loss has been largely overcome by the big wells around the Eldorado field in Kansas, some of them producing as high as 20,000 bbl. in 24 hours.

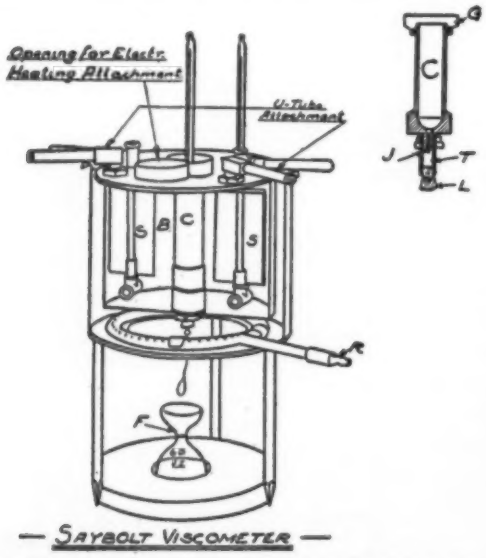
These oils are transported from the wells largely by pipe lines, with pumping stations at certain distances along the line, and today they are pumping crude petroleum from Oklahoma through these lines to Bayonne, N. J. They are also running it down from Kansas and Oklahoma through Texas to Port Arthur. There are several very large refineries, in fact, two of the largest in the world, at Port Arthur. The companies which operate two of these refine the oils there and bring them around to deep-water terminals on the seaboard. They also export to all parts of the world. Another firm which has a big terminal there brings its crude petroleum to Philadelphia, where it is refined and distributed to all parts of the United States, as well as exported in very large quantities. The oil from these deep-water terminals is shipped inland in barrels and tank cars to the various tank wagon stations, where it is distributed to the consumer, or to filling stations, and from the filling stations into the fuel tanks of motor cars and trucks.

We have in the United States what should be termed three series of crude petroleum. One is a paraffin crude, another a semi-paraffin crude and the third an asphaltum crude. Practically all the crude produced in the Appalachian Field is straight paraffin crude. Indiana and Illinois are semi-paraffine crude. A great deal of the oil in Texas is asphalt base. Some of it in the northern part, in what is known as the Electro Field, is paraffin base. Oklahoma and Kansas produce both paraffin and semi-paraffin. Southern California is practically all asphalt base. Wyoming produces both. Mexico produces practically all asphalt base crude, and recently in Oklahoma, in what is known as the Garber Field, they have found some very light paraffin crude, similar to that which is produced along the Pennsylvania-New York State line, and similar to the West Virginia crude.



CRUDE OIL STILLS





Mexico has wonderful wells, some of which are producing over 200,000 bbl. in 24 hr., and have practically maintained that output since 1916. We have it from some of the best authorities that Mexico is capable of producing 50,000,000 bbl. of crude petroleum annually, so that the outlook from that source is pretty good.

UTILIZATION OF OIL-SHALE ROCK

In addition to the wells that produce crude petroleum, we have in this country what is called oil-shale rock. There are mountains of this rock in Wyoming, Colorado, Utah, Nevada and Idaho, some of it in Missouri and some in Kentucky, and it has been estimated that it contains at least 650,000,000 bbl. of crude petroleum. The rock, when crushed and retorted, yields from 30 to 90 gal. per ton of a very good grade of crude petroleum. This is not a new industry by any means. In Scotland they have operated the shales for years and have produced good oils as well as some very high-grade paraffin waxes. Over there they have to go down for the rock, while here it is all above ground and is a gravity proposition.

Crude petroleum is a mixture of chemical compounds, all of which have their own individual boiling, fractional distillation and end points. When they are put in the still and heat is applied these various products come off as vapors at certain temperatures, the lighter and more volatile products, of course, at the lower temperatures.

OIL TESTING INSTRUMENTS

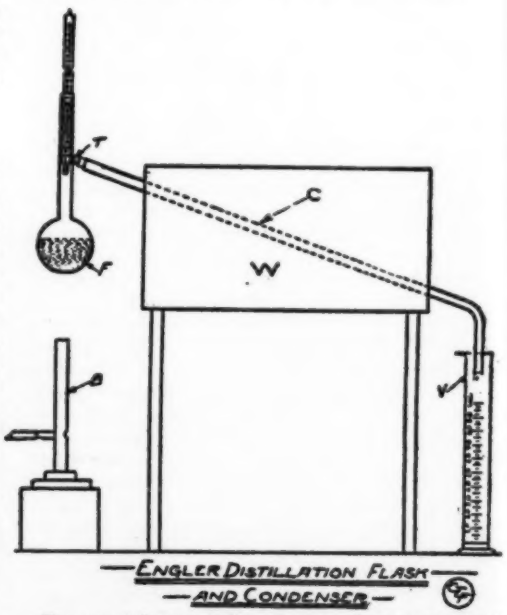
I want to show you some of the instruments used in testing oils. There are a great many physical measurements used in these tests, but a few only are really interesting to the consumer. These we hear about in every-day business.

The Baumé hydrometer, a graduated glass filled with oil, is used to determine gravity. Since water is always the same in weight at 60 deg. Fahr. we take the gravity or weight of oil at that reading. There has been a great deal of talk about gravity, particularly that of gasoline, for motor car use, and I think it has been greatly over-valued. Gravity is a guide only to the man at the refinery who is separating the products as they come from the crude oil stills. It is not of value in selecting oils. The all-important matters in selecting fuel for an internal-combustion engine are its boiling, fractional distillation and end points. The flash and fire tests are both taken with the same instrument, a Cleveland open cup and a Bunsen burner. These tests have been somewhat confused in lubricating oils. There has been a great deal of talk about high flash-test oils.

In the early days of refining, when kerosene was a product in great demand and refining was not as good as it is now, lighter oils, such as naphtha and gasoline, were apt to be mixed with the kerosene. This caused many explosions and fires with kerosene lamps, and a number of states passed laws that kerosene must not be below a certain flash point. You have probably noticed "150 flash" stenciled on the kerosene barrels. That means that the oil will not flash below 150 deg. Fahr.

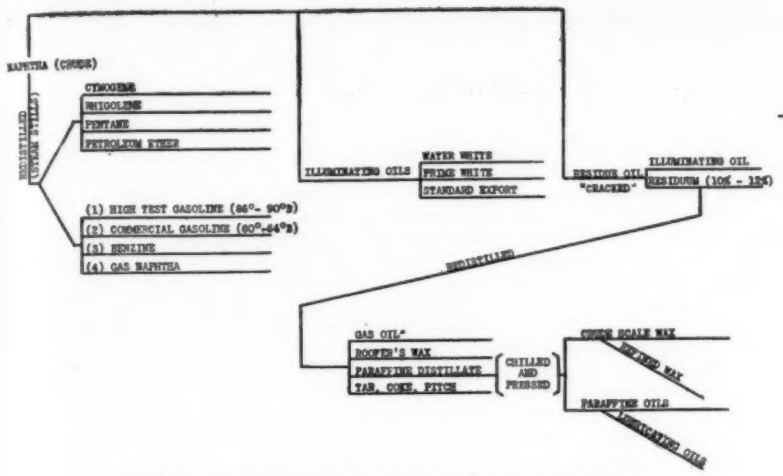
What is called a Saybolt viscometer is practically the standard for taking viscosities in the United States. It is also used for lubricating oils. Engine, machine, dynamo and spindle oils and lubricants in that class are tested at either 70 or 100 deg. fahr., but practically all the oil people today test at 100 deg. Fahr. Steam cylinder oils and the very heavy oils are tested at 210 deg. Fahr. Mineral oils decrease very rapidly in viscosity with a rising temperature and they also increase with a falling temperature; for example, an oil with 800-sec. viscosity at 100 deg. Fahr. might drop to 250-sec. viscosity at 250 deg. Fahr. At zero it would probably be 2800 or 2900 sec. Tests are taken to determine the suitability of lubricating oils for certain purposes. Viscosity measures are used in selecting oils for, say, a sewing machine or a heavy steel Pullman car, but viscosity is not a guide, by any means, to quality.

As I have already stated, all of these oils have different chemical formulas. They have their individual boiling, fractional distillation and end points. They begin to distill out of the crude at a certain temperature and end at a certain temperature.

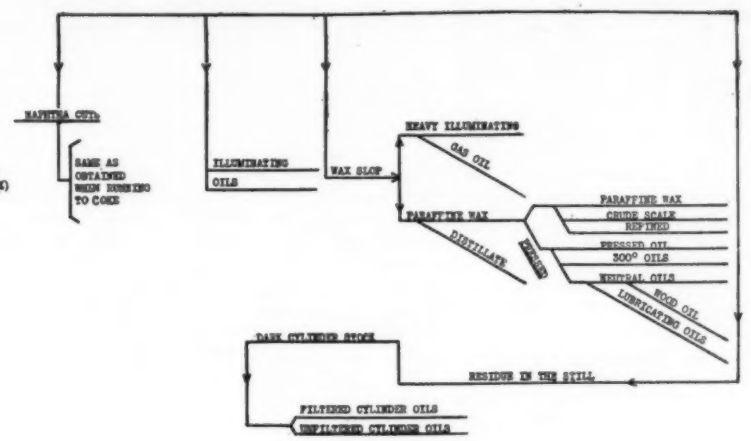


You can take a number of oils and mix and distill them; they will all distill at their own individual points. Put them back, mix them again and distill again and they will do the same thing. This quality

* From *Jour. Soc. Automotive Engineers.*



Products of distilling Oil for Dryness or Petroleum Coke



Products of distilling Oil for Cylinder Stock

has proved of great use. If any other oils are mixed in with that being tested, they show up in the distillation.

REFINERY PRACTICE

The principal products that come off in distilling what are called cylinder stocks are perhaps of some interest. To the man operating the receiving house gravity is the all-important thing as he separates the products. The first vapor to come off would be the gasoline distillate. It looks like perfectly good gasoline, but is passed to a farm tank. Sometimes they run for what is called 300 mineral seals, a heavier kerosene, used for making signal oils for railroads and for mast lamps on boats. The next distillate is a gas oil, used in making artificial gas. It is also passed to one of the farm tanks.

Runs from the paraffin crude yield a great many products that are not yielded by the asphalt crude. The gas oil distillate is followed by what is called the paraffin wax distillate. This goes to a farm tank. What is left in the tank now is referred to as 600 steam refined stocks. These can be still further reduced and separated into various grades of stock. The heavier portion of them is called crude petrolate, or commercially, vaseline. It can be filtered, heated to a high temperature and passed through fuller's earth and bonedust until it becomes perfectly white.

There is another process in refining the paraffin as well as the semi-paraffin oils, that is called running to dryness or to coke. It is practically the same and the products are the same until the steam cylinder stock left in the stills is reached. In the tar stills this cylinder stock is prepared for a higher temperature, and cracked into what is referred to by the trade as 28 paraffin. It is a very light-bodied oil, used largely for making greases. A 25 pale paraffin oil is obtained that looks very good and is very good for certain purposes. A heavy oil called 25 red and an even heavier, known as 23 gravity paraffin, come over as well.

The semi-paraffin crudes yield a great many of the same products as the paraffin crudes, but the grade of steam cylinder stock is not as good. The asphalt oils yield about 5 per cent of gasoline distillate, 10 to 12 per cent of kerosene distillate and the rest in the form of lubricating oils. There is very little if any paraffin wax in the asphalt crude. In running to dryness or to coke petroleum coke is left in the still. It is one of the purest forms of carbon. In wet distillation we do not get any coke.

FARM TANK STORES

Let us go back and see what is to be done with the various products held in the farm tanks. The naphtha cut can be brought back to the stills and further separated into a line of products with very light gravity and very low boiling point—cymogene, rhigolene, pentane and petroleum ether. Those are so light as to be almost gas, and they have to be kept cold. They derive their names from their chemical formulas.

The second cut yields high-test gasoline which would be 86 to 90 Baumé. The commercial gasoline is 60 to 64; then come benzine and gas naphtha. In the second cut come the illuminating oils also. They go back to the still and are fractionated into water-white, prime-white and standard export. The water-white is the high-grade kerosene. Prime-white is not as good in color and not as high in fire test. The standard export is our coarse grade of kerosene. All of these various products are not run by any one manufacturer.

Everything that is left is crushed, put into a still and redistilled at high temperature under pressure, the small molecules breaking up until they yield a number of different light oils. A skimming plant, for instance, will put the crude oil in the still and take off the gasoline distillate. This they may refine further themselves or sell, and they will sell all the remainder as fuel oil. They may take off down to a certain product, say vaseline, sell the product as fuel oil and specialize on the vaseline. From the residue some curious products are obtained, such as roofers' wax, a very heavy, sticky substance, used in the manufacture of artificial leathers and in making other leather goods. Crude scale wax is cracked from the paraffin distillate. This is taken to the wax house, where it is put into hydraulic presses and refrigerating machinery and solidified. The oil is pressed out and the wax is sold as crude scale, semi-refined or pure refined.

The pressed oil again goes back to the steam stills and from it some 300 oils are distilled as well as the neutral oils. Some of these are very light in viscosity and color and are called non-viscous neutrals. They are used largely as lubricating oils in very light machinery. For certain purposes these oils are placed in large, open, flat tanks on top of warm water and bleached by the rays of the sun. For other purposes they are further refined and are filtered to color through fuller's earth and bonedust. These are called sun-bleached, bone-filtered neutral oils. Some of the heavy red neutrals belong in this class. Those are the best oils that can be made from the paraffin crude.

Left in the still is the dark cylinder stock, the 600 steam refined stock. I have shown how, by another process, this is cracked up into paraffin oils. It is carried back to the steam stills and further reduced into various grades of cylinder oils, running in viscosities of about 140 sec. at 210 deg. up to about 200 sec. The lighter oils are used for steam cylinder lubrication. Some of them are compounded with tallow oil or with lard oil, and sometimes a mixture of the two, depending upon what the oil is to be used for. The higher viscosity and the higher flash-test oils are used for superheated steam cylinder lubrication where temperatures are very high, and they are also used for differential and transmission oils.

Neutral oils from the paraffin crudes are seldom above 200 sec. viscosity, so that to secure higher viscosity for gas-engine lubrication, heavy tractors and extra heavy automobiles, a neutral oil and what is called a cold-test filtered cylinder oil are mixed.

CONSERVATION OF PETROLEUM PRODUCTS

As I have shown you, there is an enormous production of crude petroleum and great possibilities in producing oils from the shale rock. None the less we should conserve all petroleum products, not any one of them, but all of them. While we have a very large visible supply, there is a strong movement toward the use of oils as fuel all over this country. A great number of ships are under construction and practically all of them will use oil as fuel. This means that the gasoline distillate will be extracted from oils to make the flashpoint safe for the bunker oils and we shall lose all the lubricating oil, all the paraffin wax, vaseline, coke and other oil products. We do not yet know what may come out of Mexico. There is a wonderful oil field down there, but we all realize what the conditions are. This business is very hazardous. We cannot expect very many men to invest heavily under the circumstances.

More oil is wasted than is used. I will venture to say that 96 per cent of the complaints investigated on the lubrication of gas, automobile and truck engines are based on the excessive use of lubricating oil. We waste as much oil as is needed to lubricate all the automobiles in this country. As much oil passes the piston and is burned up as we consume in actual lubrication. If you will investigate your own troubles, you are likely to find that a great many of them are traceable to excessive use or the wrong grade of lubricating oils.

I have explained some of the important physical measurements in use today, but these measurements are no guide to value in selecting oils for internal-combustion engines. Viscosity is a guide to suitable body, but there are two qualities in a lubricating oil for which there is no measuring apparatus. Quality in lubricating oils means two things, cohesion and adhesion. By cohesion we mean that quality of an oil which permits the particles forming it to stay together at high temperature. Adhesion is the quality which permits an oil to stay on the walls of a cylinder, on the pistons and piston rings, at high temperature. Without that quality lubrication is not the best possible; we do not get out of a gallon of fuel the mileage that we should.

It is hardly likely that the fuel of the future will be any lighter than it is now; if anything, it will be heavier. Unless we develop some means of introducing fuel into the explosion chamber in practically liquid or vapor form, more fuel instead of less will pass the piston.

Electricity in Agriculture.

According to the *Elektrotechnische Zeitschrift* the prejudice of the German farmers against electrical appliances has now been overcome, and they are being used for a variety of purposes.

Small progress has been made with electric ploughing machines, but the war has produced a great development of ploughs driven by petrol engines. Threshing machines driven by electric motors have become extensively used, mechanical milking machines have been found incapable of replacing milking by hand, and electrically-heated hatching machines are coming into favor.

The stimulation of the growth of crops by subjecting them to electric radiation has not yet become practical owing to the lack of physiological knowledge of plant growth, and the absence of data from which the best voltage and form of current can be ascertained. It has, however, been demonstrated that the humidity of the air plays an important role in determining the effect of the electric radiation. The use of artificial illumination of crops certainly hastens growth, but the cost is such as to render it commercially useless. The drying of crops by electric heaters is effective, but too costly; on the other hand, the drying process has been carried out successfully, for example, at Duisburg, by utilizing the waste heat of electric generating stations. Promising experiments have also been performed at the Dresden Technical College in the artificial heating of the ground by the waste heat of such stations.—Abstracted by *The Technical Review*.

The Use of Raw Tars as Fuel for Diesel Engines*

Some of the Disadvantages and Methods of Overcoming Them

By Harold Moore, M.Sc.Tech.

THE development and commercial success of the various types of internal-combustion engines running on liquid fuels have been almost entirely governed by the economics (i.e., price, available quantity, import tariffs, etc.) of the fuels which they were designed to employ. When the constant-pressure cycle engine or Diesel engine was first sold as an oil engine the available margin of choice of fuels was very narrow. Kerosene, the fraction obtained between 150 deg. and 300 deg. C. in the distillation of petroleum, was suitable, and the heavier distillates such as solar and gas oils were also found to be satisfactory fuels. The range of fuels was then increased by including the better grade "crude oils," which usually consist of depetrolised crude petroleum. As a result of the economic advantage obtained by burning the poorer grade petroleum residua, improvements in the design of engine were introduced, and consequently the major portion of the heavy petroleum residua became available for service in Diesel engines. Certain of the highly asphaltic petroleum residua are, however, still outside the range of fuels suitable for general use.

The difficulties of transport and the large demands of the Admiralty for heavy oil during the early part of the war resulted in the adoption of the heavier tar distillates as substitutes for petroleum, though previous to the war there had not been sufficient advantage in price to warrant the change from petroleum oils to tar distillates when the lower heat value of the latter was taken into account. Tar distillates and even raw tars had been successfully employed on Diesel engines on the Continent at an earlier date as a result of the acute petroleum shortage caused by import tariffs, and a considerable portion of the tar oils employed in this country during the war were utilized with the assistance of the pilot ignition gear, a device which had been invented and developed on the Continent before the war.

Numerous papers have been published in which information concerning the use of tar distillates on Diesel engines has been given, and the writer has dealt with this subject at considerable length elsewhere.

We may summarize our knowledge of the chemical and physical properties of tar oils, and our practical experience of their behavior in Diesel engines by the following remarks:

1. The temperatures of spontaneous ignition of tar oils are much higher than those of petroleum oils. This results in ignition troubles when employing engines of standard design.

2. Tar oils are liable to form precipitates under the action of heat and compressed air. This may result in obstruction of the atomizing devices.

3. Tar oils are richer in carbon and lower in hydrogen content than petroleum oils; and they are therefore more liable to precipitate carbon on the walls of the combustion space if not burnt under entirely favorable conditions. The main effect of this property of these oils is an increased wear on the exhaust valve face and seat.

The ignition difficulties with tar oils have been overcome by the employment of a variety of devices of which the pilot ignition system, which provides for the introduction of a small charge of a petroleum or shale oil into the cylinder prior to the main fuel charge, has been the most generally utilized. Obstruction of the normal atomizing devices hes become less frequent since greater attention has been given to the analyses of the tar oils, and this trouble has been overcome in several instances by the use of atomizers of special design. The increased wear of exhaust valves when employing tar oils is not very great, and only necessitates more frequent attention to this part.

Since the end of last year the price of the heavy tar distillates has rapidly increased, while the prices of the competing imported petroleum fuel oils have fallen. The economic advantage to be gained by burning tar oils has therefore largely disappeared.

The prices of raw tars have during the last ten years been somewhat less than half the price of the heavy tar distillates, while their average heat value is only about 6 per cent less than that of the tar oils, or approximately 15 per cent. less than that of the average petroleum oil. Also the tar oil supplies of the country are limited, the yield of heavy tar distillates from an average tar is approximately 33 per cent. Thus the supply of tar is three times as great as the quantity of tar oils prepared in the country. A large portion of the raw tar is quite unsuitable for direct burning in internal-combustion engines. Such tar is, however, valuable to the distiller and capable of yielding the creosote which is required for export to the American timber creosoting industry. As the raw tars present a favorable source of fuel for Diesel engines when viewed on general economic grounds, i.e., as regards price, quantity available, facilities for distribution, etc., a few notes on both their properties as fuels may be of use to both manufacturers and users of Diesel engines.

Raw tars, when used as fuels for internal-combustion engines possess to a greater or less extent all the defects of tar oils, and in addition certain defects peculiar to themselves. There is also much wider variation in the physical and chemical properties of the different tars than the usual limits of variation observed in the analysis of tar oils. This latter fact necessitates the continual and most detailed analysis of raw tars, not only tar from each new source requiring analysis, but each new delivery.

Raw tars generally possess spontaneous ignition temperatures about the same or slightly lower than those of tar oils (about 200 deg. C. higher than the average petroleum oils; i.e., about 460 deg. C. for tar oils and 260 deg. C. for petroleum oils), and they present the same ignition problems. This difficulty has in many cases been overcome by adopting the pilot ignition system and using a petroleum oil for ignition purposes. Some large Diesel-engine installations on the Continent are said to have worked satisfactorily with raw tars, using a small pilot charge of the tar itself injected into the cylinder considerably in advance of the normal timing. The use of petroleum for starting purposes, which is a common practice when burning tar oils, presents greater difficulties when employing raw tars as main fuel, as deposits are formed by the addition of petroleum to raw tar, and these are greater in quantity and more viscous than the deposits which are formed by tar oil-petroleum mixtures. These deposits interfere with the working of the fuel-pump valves. Specially-chosen tars of low free carbon content do not so readily cause obstruction of the atomizing devices as do certain tar oils. Whereas tar oils usually either keep clean or else readily cause obstruction, the tars more usually cause slight obstruction. It is, however, preferable to employ special atomizing devices for use with raw tars. The deposits formed in atomizers when running on raw tar are probably caused by the accumulation of free carbon.

A trouble frequently encountered when burning raw tars or other pitch or asphalt containing fuels is the formation of gummy deposits on the fuel valve stem, which is due to the partial distillation of fuel which has crept up the fuel valve. This may readily interfere with the working of the valve. It is a trouble seldom encountered when burning tar oils. It can be surmounted by the employment of devices for preventing the creeping of fuel up the valve stem.

The third trouble mentioned as being experienced in burning tar oil is the extra wear on the exhaust valve caused by precipitation of carbon when the conditions of combustion are not satisfactory. The same trouble is occasionally encountered when burning petroleum under favorable conditions.

The wear on the exhaust valve is much more pronounced when burning raw tar than with petroleum oils or tar oils. Whereas with the latter fuels it is only necessary to prevent the precipitation of carbon, with raw tars precipitated carbon is already present in the form of the so-called "free carbon," and for satisfactory running it is essential to burn this free carbon during the cycle before the opening of the exhaust valve. On account of the particles of free carbon burning less rapidly than the remainder of the fuel there is considerable danger, when burning raw tars, of the exhaust valve opening before the combustion of the free carbon particles is complete. If incomplete combustion takes place glowing particles are trapped between the valve face and the seat, which results in pitting of the valve face, and this, if allowed to become pronounced will cause loss of compression and subsequent starting troubles. Seizure of the exhaust valve stem is also likely to occur. Increase of compression causes higher temperature in the combustion space and therefore accelerates combustion. High engine speeds afford less time for complete combustion, and therefore cleaner running is experienced at slower speeds, a fact which the Continental makers appear to have realized, as Continental engines running on raw tars generally work at low speeds.

The majority of petroleum and tar oils contain less than 0.02 per cent. of ash, and it is rarely therefore, that ash troubles are noticeable on engines employing these fuels. As tars contain much greater quantities of ash, and in many cases cannot be employed on account of ash trouble, a much greater wear on the piston rings and liner may be expected when engines are running on tars than when employing tar oils.

As raw tars are frequently high in viscosity there is often difficulty in freeing tthem from water, which does not readily separate out. The presence of water causes misfiring and irregular running.

The removal of water from raw tars presents considerable difficulty, the only method which finds general use being by "settling" or allowing the tar to stand for two or more days in large storage tanks, which are maintained at a temperature of about 100 deg. F.

The removal of water from carburetted water gas tar has been effected by the use of centrifugal machines. This tar is particularly difficult to separate from the water as the specific gravities of the tar and the water are about the same values, the tar averaging about 1.05 specific gravity, and the water, owing to salts in solution, being about the same. In order to facilitate separation, brine may be added to the wet tar, thus increasing the density of the aqueous portion, while warming the mixture further increases the difference in densities as the coefficient of expansion of the tar is greater than that of water. These measures may be employed when adopting either the centrifugal or settling methods of separation.

It has also been claimed that centrifugal treatment removes some of the free carbon and some of the ash content of tars. Filter press treatment has not been found to remove satisfactorily either free carbon or ash. It has recently been claimed that the percolation of the tar through gravel filters is a method of removing some of the free carbon from tars. The removal of free carbon from tar has been successfully carried out in the United States by filtering under high pressure through wooden plugs, the liquid portion of the tar passing longitudinally down the grain of wood.

On account of the high viscosity of tars it is generally advisable and sometimes absolutely necessary to employ a preheater, so situated that it will insure the oil being warm when passing through the service pipes. Such preheaters may derive their heat from the exhaust circulating water supply, high-pressure delivery pipe from compressor, or from a separate source, e.g., from an electric resistance. The latter type possesses the advantage of being independent of the engine and consequently it being possible to heat the oil before the engine is started up.

The Properties of Tars.—Both the yield and the chemical constitution and physical properties of tars depend mainly upon the following factors:

1. The nature of the coal from which the tar originates.

2. The rate of heating the coal during carbonization.

3. The maximum temperature to which carbonization is carried.

4. The speed and method of removal of the volatile products from the retort during carbonization.

Coals rich in volatile matter yield comparatively large quantities of tar. Rapid heating of the charge during carbonization tends to reduce the quantity of tar and to form tars rich in free carbon and aromatic compounds. Gradual raising of the tem-

* From *Engineering* (London).

perature of the retort or oven results in greater yields of tar, with lower free carbon content and a higher proportion of aliphatic hydrocarbons.

A high maximum temperature insures complete removal of volatile matter from the coke and raises the proportion of free carbon and aromatic compounds in the tar. Rapid removal of the volatile matter from the retort insures high yields of tars comparatively free from free carbon and rich in aliphatic bodies.

From the Diesel engine user's point of view we require large yields of tar rich in aliphatic bodies and low in free carbon content.

Gas works in this country employ plant of three types: horizontal retorts, inclined retorts and vertical retorts. Horizontal retorts are generally present in the older installations; modern plan consists more frequently of vertical retorts.

The horizontal retorts do not allow sufficiently rapid removal of volatile products, and are also so constructed that the volatile products pass along the retort walls and become decomposed, which results in low yields of highly viscous black tar, rich in aromatic bodies and free carbon.

Vertical retorts may be worked either intermittently or continuously, but in both types the conditions are such that high yields of mobile dark brown tars result. These tars are comparatively low in free carbon content and rich in aliphatic bodies, and are therefore particularly suited for use on Diesel engines. The tar from Dessau intermittent vertical retorts has been used in quantity on Continental Diesel engines.

Inclined retorts give tars more closely akin to the tars from horizontal retorts, though usually slightly lower in free carbon content.

Coke ovens vary considerably in construction, and the tars obtained from them are very irregular in their properties. Of the coke oven tars examined by the writer those originating from Simon Carvé ovens were found most suitable for use as fuel for Diesel engines.

—	Specific Gravity.	Ash.	Coke.	Free Carbon.	Net Heat Value in Calories. (Dry Tar.)	British Thermal Units.
		per cent.	per cent.	per cent.		
Horizontal retort tar ..	1·15 to 1·23	0·0 to 0·1	20·0 to 35·0	15·0 to 30·0	8,700 to 8,850	15,660 to 15,930
Inclined retort tar ..	1·12 to 1·19	0·0 to 0·1	15·0 to 25·0	10·0 to 20·0	8,750 to 8,900	15,750 to 16,020
Vertical retort tar ..	1·05 to 1·12	0·0 to 0·1	5·0 to 10·0	1·0 to 7·0	8,800 to 9,000	15,840 to 16,200
Coke oven tar	1·08 to 1·29	0·0 to 0·3	5·0 to 25·0	1·0 to 25·0	8,600 to 9,250	15,480 to 16,650
Low temperature carbonisation tar	1·05	0·1	8·0	2·0	8,776	15,797
Oil gas tar	1·03 to 1·12	0·0 to 0·4	8·0 to 10·0	0·3 to 5·0	9,100 to 9,500	16,380 to 17,100
Lignite tar	0·96 to 1·09	0·07 to 0·4	0·5 to 7·0	0·0 to 5·0	9,100 to 9,800	16,380 to 17,640

Composition of Various Tars

In addition to the gas works and coke oven tars, certain tars from low-temperature carbonizing plants have been examined with a view to their use on Diesel engines. These tars have been obtained by the carbonization of coal at low temperatures in plants provided with special arrangements to insure the rapid removal of the volatile products. The free carbon content of such tars is very small, and the hydrocarbons of which the bulk of the tars consists are mainly aliphatic.

The removal of water from the tars presents a serious difficulty, as the water is emulsified and cannot be separated by the usual method of warming the mixture and allowing it to settle.

The above-mentioned tars are all derived from coal, but tars from other sources, particularly lignite tars, must not be overlooked.

Lignite or brown coal is found in large quantities in Saxony, where a highly- developed lignite industry exists. Though it is not worked in this country, lignite fields are widely spread over the British Empire. By destructive distillation lignite yields a brown tar of buttery consistency, which consists mainly of aliphatic hydrocarbons. This tar is practically devoid of free carbon, but rich in solid hydrocarbons of the unsaturated alphatic series (akin to paraffin wax).

This tar, according to Continental authorities, can be satisfactorily burnt in Diesel engines without ignition gears or any other special modifications. It behaves in the engine similarly to petroleum and shale oils.

By the carbonization of peat a mobile tar of the aliphatic type is obtained. This might prove a suitable fuel for heavy oil engines, but at present the carbonization of peat is not being carried out on a sufficiently large scale to allow of the use of the liquid products for fuel purposes.

It is common practice in normal times for gas works in this country to manufacture a portion of the lighting gas by "cracking" a heavy petroleum distillate and mixing the resulting oil gas with water gas. During this process oil gas tar, also known as "carburetted water gas tar," is produced.

This tar is not a coal tar, but originates from petroleum. It is frequently mixed with water in the form of emulsion, and the greatest difficulty is then experienced in effecting its separation. Though a product of petroleum, oil gas tar consists mainly of aromatic hydrocarbons, the larger portion of the original hydrocarbons having undergone complete transformation during the cracking process.

When free from water and ash, oil gas tar behaves in a Diesel engine in a very similar manner to tar oil, but does not cause pulverizer choking. The ash content of oil gas tar is very variable, and when attempting to run on this fuel analyses of each batch for water and ash content must be made before accepting delivery.

The usual composition of tars is shown in the table.

Of the tars given in the above list those from horizontal and inclined retorts have hitherto proved quite unsuitable for use in internal-combustion engines on account of their high free carbon content.

Intermittent vertical retorts (of the Dessau type) are largely used in Germany, and yield tar or slightly lower average free carbon content than that from continuous vertical retorts, of which a large number are installed in this country.

Some of the tar obtained from coke ovens might be used for engines, but probably the quantity would not be very great. Oil gas tar is not being produced in great quantity in this country at the time of writing on account of the high price of petroleum oil, and even in normal times the quantity available is comparatively very small. Neither low temperature carbonization, peat distillation, nor lignite carbonizing plants are working in quantity in this country.

Of the tars mentioned, only vertical-retort tar and some coke-oven tar are available for use in quantity, and it is on these, particularly on vertical-retort tar, that we shall have to concentrate our attention in the near future. Tar from vertical retorts and coke ovens was available before the war at a price of about 30s. per ton, while tar oils were commanding a price of about 60s. per ton. The price of the distillate is usually slightly over double the price of the raw produce. Though the heat values of suitable tars are approximately the same as those of tar oils they show slightly higher consumptions per brake horse-power-hour as the thermal efficiencies are reduced by the higher viscosity of the raw product.

With engines of over 100 brake horse-power the full-load consumption for raw tars is approximately 0.55 lb. per brake horse-power hour. Certain allowances would have to be made when engines are to run on raw tars. It is to be noted that:

1. The maximum mean effective pressure on the engine will be slightly lower than the normal.

2. The speed of engines running over 200 r.p.m. would probably have to be reduced, with corresponding reduction in load.

3. The attendants would have to be more skilled than is normally necessary.

4. The wear and tear on working parts of engine would be slightly in excess of the normal.

In spite of these disadvantages there should be a marked economy due to the great difference in fuel costs.

A specification to insure a suitable quality of tar for use in Diesel engines would have to be drawn up on the following lines:

1. The tar must possess a specific gravity below 1.12.

2. The tar must not contain more than 0.08 per cent. of ash.

3. The tar must not contain more than 2 per cent. of water.

4. The tar must yield at least 9,100 calories gross heat value (16,380 British thermal units).

5. The tar must not contain more than 6 per cent. of free carbon (insoluble in mixture of toluol and glacial acetic acid).

6. The tar must not yield more than 10 per cent. coke value.

Clauses 1 and 6 would insure the tars not containing excessive amounts of pitchy substances. The water, ash and free carbon limits are fairly stringent, and would prevent certain tars from satisfying the specification; they are, however, necessary.

REVIVAL OF INDIGO.

In addressing the Textile Institute, at Bradford, on this subject, Prof. H. E. Armstrong took exception to the application of the adjective natural to indigo as redundant, also to the use of the expression synthetic indigo—as indigo never has been and never can be made artificially. Indigo is a mixed material, produced in a particular way from a plant, containing, in the case of well-made samples, about 70 per cent. of the specific compound indigotin. This compound, not indigo, is the substance which is being manufactured and sold in an almost pure form. The term indigo should be used only in speaking of the natural product.

Indigo contains substances other than indigotin which have an influence in the dye vat, even if not actually dyestuffs. It has been the studied policy of the German manufacturers to disregard these associated materials as of no account; all but the old conservative school of dyers have fallen into the trap; these latter have always maintained that indigo has special qualities, which give it an advantage, in dyeing heavy shades, over manufactured indigotin pure and simple. Probably, in future, this difference will be one of determining influence in the industry.

In trials made with special care to contrast indigo with synthetic indigotin, in dyeing heavy shades on loose wool, the former has been found to have the advantage to a very marked extent. Hydrosulphite vats (1500 gallons) were set with equal quantities of indigo and of synthetic indigotin paste, each containing 20 per cent indigotin, and equal quantities of loose wool were dyed simultaneously in the two vats in lots of 50 lb. at a time. In the case of the first two or three dyeings deeper shades were obtained in the indigo vat. In consequence, the addition of paste before dyeing each lot of wool was gradually reduced, and it was eventually found that equal depths of shade were produced when the amount supplied each time was 8 lb. of synthetic paste and only 6½ lb. indigo. Indigo produces a rather redder and brighter shade even when these proportions are used. The difference is being made the subject of systematic inquiry.

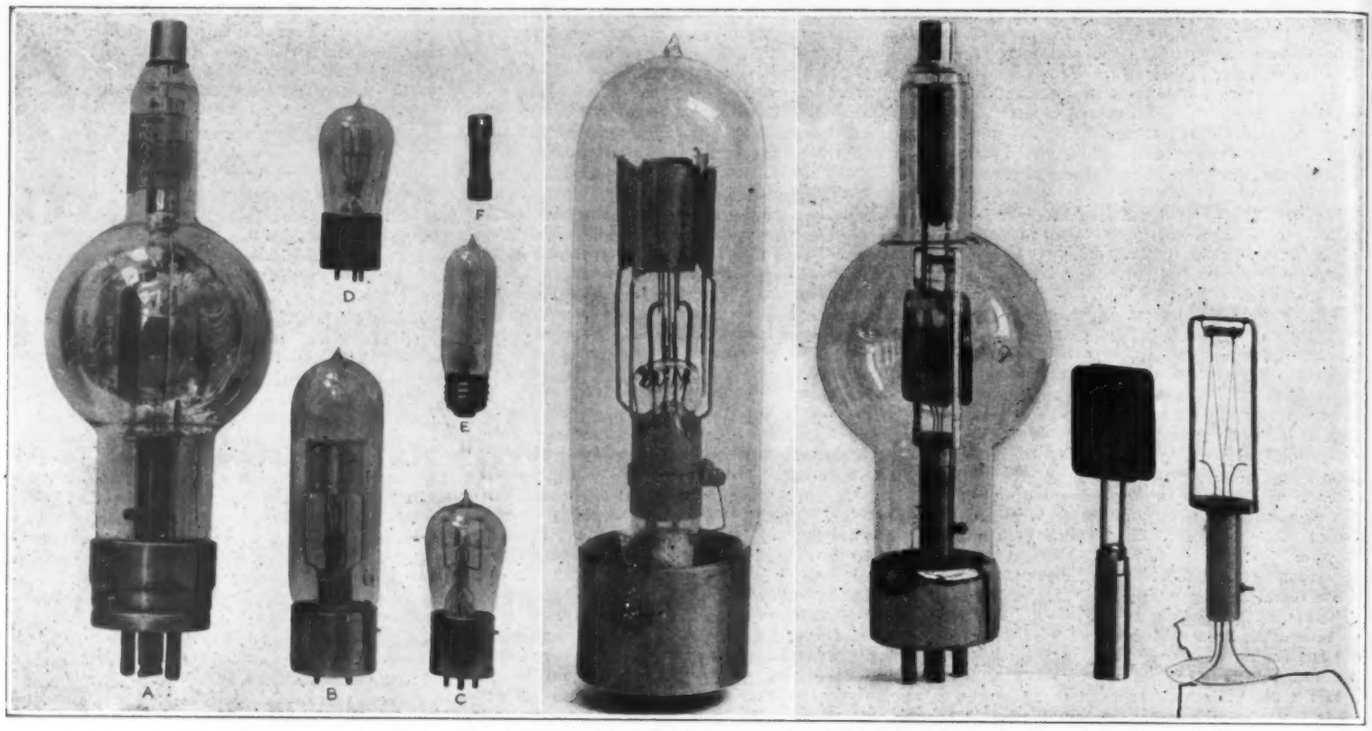
After considering the history of the introduction of synthetic indigotin and the position of indigo prior to the war, especially the great reduction in output of the natural product, Prof. Armstrong gave an account of the efforts made to improve the industry in India, in particular of late in Bihar, under the direction of Mr. W. A. Davis. It has been shown conclusively that a paste containing a standard proportion of indigotin, comparable with that in the synthetic paste on the market, is easily prepared, and that the only disadvantage it has arises from the presence of a certain proportion of insoluble matter. An organization for the preparation of such paste has been established, and probably this material will be put on the market in competition with synthetic paste. Other forms, more easily transported, are in contemplation, however.

The process of manufacturing indigo has been much improved under Mr. Davis's direction—in particular the yield has been raised considerably by the recovery from the "seet" water of the finely divided, suspended indigo, which formerly ran to waste. This has been effected by adding Dhak gum.

The extraction process is being studied in every particular, especially on the bacterial side.

The crop has been a declining one of late years, owing to the diminished yield per acre, the occurrence of wilt disease, and the attack of the plant by an insect pest; also by reason of the difficulty of raising seed. A careful and extended survey of the results has led Mr. Davis to the conclusion that, at all events, the main cause of the decline is the depletion of the soils in available phosphate. Of late, even the Natal-Java plant has ceased to give a superior yield—the early success of this variety is shown to have been due to the fact that it is a very deep-rooted plant and was able to appropriate from the sub-soil the phosphatic supplies beyond the reach of the Sumatrana plant.

The future of the industry appears to be mainly contingent on the extent to which planters are able



At the left: Various types of vacuum tubes for transmitting and receiving. *A*—large transmitting tube of 250-watt capacity, using a plate current of 1,500 volts. *B*—medium-sized transmitting tube of 50-watt capacity, using 750 volts for the plate current. *C*—Small transmitting tube of 5-watt capacity, using 300 volts for the plate current. *D*—Small receiving tube. *E*—Ballast lamp...*F*—Grid leak resistance...*Center*: Enlarged view of medium-sized transmitting tube shown at *B*. *At the right*: Large transmitting tube of 250-watt capacity and its components.

TRANSMITTING AND RECEIVING TUBES OF THE GENERAL ELECTRIC DESIGN, DEVELOPED DURING THE WAR.

Experimental Wireless Telegraphy and Telephony—VII*

Simple Explanation of the Operation of Vacuum Tubes as Applied to Radio Communication

By Louis Gerard Pacent and Austin C. Lescarboura

(*Continued from* SCIENTIFIC AMERICAN SUPPLEMENT, *No.* 2383, *October* 11*th*, 1919, *Page* 225.)

A wireless station without a vacuum tube is years behind time. The vacuum tube, which radio amateurs and professionals are pleased to call by various names, such as electron tube, audion, thermionic tube, kenetron, pliotron, oscillion, dynatron, electron relay, audiotron, and so on, is the basis of present-day radio communication. Indeed, in its present stage of refinement it is directly responsible for the successful application of wireless telephony to aircraft, which has served a very distinct purpose in the winning of the world war. All in all, the vacuum tube has played a leading part in the general advancement of radio communication.

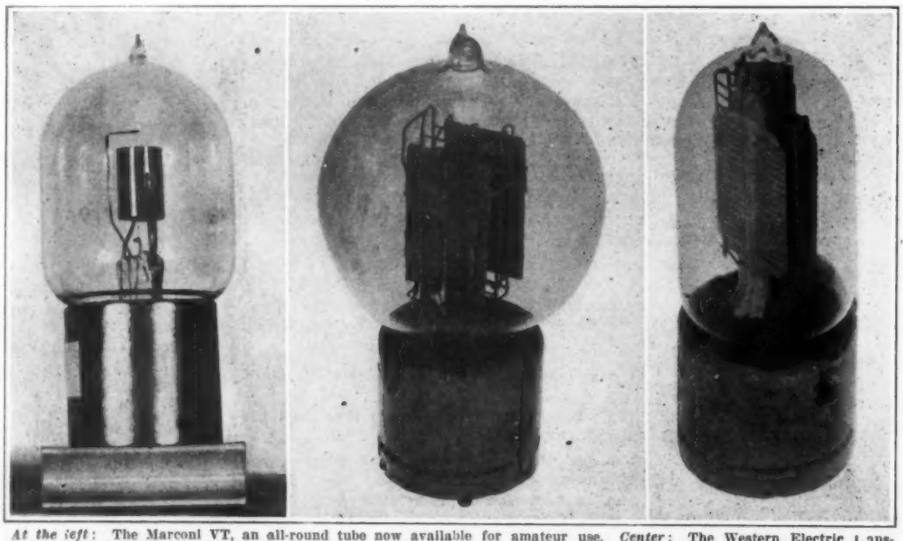
The vacuum tube can be used for a variety of radio purposes, such as to generate alternating currents of any frequency, to amplify and rectify faithfully any current or voltage available, to modulate radio or audio oscillations as well as to detect them better than any other existing type of detector. The vacuum tube makes possible the reception of European radio stations with a small loop as the antenna, and the amplifying of all signals manifold so that they can even be heard throughout a large room.

THEORY OF THE CONDUCTION OF ELECTRICITY THROUGH GASES AND ELECTRON CURRENT FLOW IN VACUUM TUBES

For almost two centuries it has been known that air in the immediate vicinity of incandescent metals is always a conductor of electricity. It was Edison who discovered that negative electricity passes from a carbon filament to an electrode placed in an incandescent lamp bulb, and who made use of the phenomenon by rectifying alternating current so as to produce undirectional current. This phenomenon has since been called the Edison effect, and its exact action depends upon the fact that when a metal is heated in a vacuum it gives off electrons or small particles of electricity.

A vacuum tube is nothing more or less than the working out of the Edison effect. It is simply an incandescent lamp with one or more electrodes inserted in the vacuum. Now, if we connect a battery *B*, as shown in the first sketch, between the heated filament and the auxiliary electrode or plate in the vacuum tube so as to make the plate positive in potentional with respect to the filament, the electrons are captured by the plate *P*, so to speak, preventing them from returning to their origin—the filament *F*. The battery thus causes a continuous electron flow of electricity from the filament to the plate without any direct electrical connection between them. This electric current ceases to flow when the filament is cold, because no electrons are flowing from the metal. No current will flow if the battery *B* is connected wrong, because of the fact that the plate is then negative with respect to the filament F and the electrons will be repelled back into the filament. The electron or plate current varies with the filament temperature if the plate voltage is kept constant (see the two curves for characteristics).

Most of the pre-war vacuum tubes did not behave exactly in accordance with the theory mentioned in the foregoing paragraph, because the degree of vacuum was insufficient and gases



At the left: The Marconi VT, an all-round tube now available for amateur use. *Center*: The Western Electric transmitter tube, designed for use as an oscillation generator and modulator. It operates with a filament current of 1.35 amperes and a plate voltage of 350 volts. In a properly designed circuit this tube will deliver at least 5.7 watts in the form of oscillating current. *At the right*: The Western Electric receiving tube, which operates both as a detector and amplifier. It requires a filament current of 1.1 amperes at 2.5 volts, and a plate potential of 22.5 volts. When used as an amplifier a space current of approximately 3 milliamperes is obtained with a plate voltage of 34 volts and a filament current of 1.1 amperes. Under these conditions it will give a minimum power amplification of over 200 fold, and has an exceptionally long life of more than 3000 working hours.

SMALL VACUUM TUBES FOR RECEIVING AND TRANSMITTING PURPOSES

were present in the tubes, which rendered them unstable. In fact, their operation was very changeable; one day one result would be obtained, while the next day, under almost the same conditions, the results obtained would be entirely different. This was caused by the action of the interior residual gas, which affected the electron flow in various ways. One great disadvantage of the gas-filled vacuum tubes of pre-war days, such as the "audion," was that due to the collision of electrons (small particles of electricity) with atoms (small gas particles). Such collision produced ionization, which in turn resulted in a very large plate current. Although the reader at first might consider this an advantage, the actual results did not justify this thought, because the filament's life was greatly reduced by the bombardment taking place in the tube and because a large battery voltage usually causes a "blue glow" in the tube, which in turn causes the tube to behave very erractically and uncertainly, both as a detector and an amplifier.

THE FLEMING OR TWO-ELECTRODE VALVE

The Fleming valve is a device taken from the original Edison effect already described, and may be considered the first vacuum tube detector employed for rectifying radio frequency currents. It was developed by Prof. J. A. Fleming, a well-known radio engineer of England, who has been associated with Marconi in much of his experimental and technical work.

The first of the accompanying diagrams shows a Fleming valve as used by various radio companies and radio experimenters. Its action is somewhat like a crystal detector. This rectifying action is caused by a current flowing in the vacuum when the negative terminal of a battery is applied to the heated filament and the positive one to the plate, as indicated in the sketch.

A modern form of two-electrode vacuum tube is the Kenetron, developed by the General Electric Company. This has a very good vacuum compared with the Fleming valve, and is made in various sizes and styles. It is used principally for rectifying high voltages and low frequencies in X-ray work, but it has also been found most useful in rectifying high voltage currents for use on plates of high-power three-electrode and multi-electrode vacuum tubes, thereby doing away with the expense and trouble of a special high-voltage direct-current generator.

Kenetrons are also made in somewhat special design for charging storage batteries from the usual alternating-current supply. These special tubes are known as Tungar rectifiers, and contain argon gas in rarified form which, as described earlier in this discourse, helps to produce a large electron flow through ionization by collision. They are made in several capacities fit various requirements.

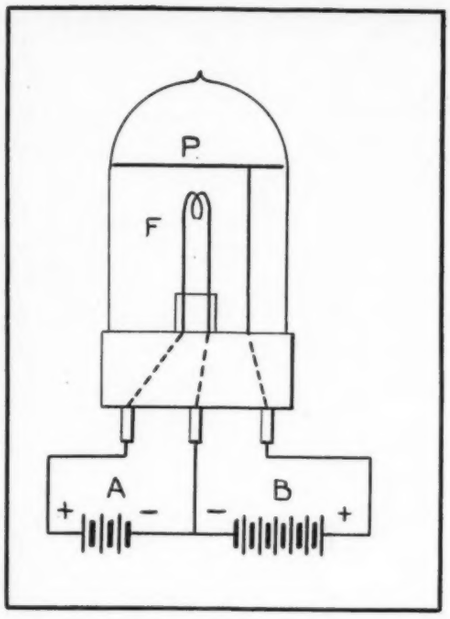
THE THREE-ELECTRODE VACUUM TUBE

The fact remains, however, that two-electrode vacuum tubes are now employed in very few instances for radio communication. The three-electrode vacuum tube has been rapidly replacing the two-electrode tubes and, indeed, has been replacing practically all other forms of detectors because of its super-sensitiveness and its operating convenience. It has long been a well known and fully appreciated fact that the two-electrode vacuum tube is not as good a detector as most crystal types, and for that reason this branch of the art has lain more or less dormant until the introduction of the third or controlling electrode in the tube, by Dr. Lee DeForest, a wireless experimenter and inventor whose career dates back to the early days of radio.

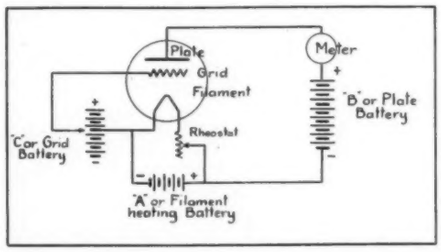
The introduction of the third or controlling electrode made vacuum tubes what they are today. It opened up vast possibilities in the wireless field in particular and the electrical and scientific fields in general. Many of the great advances of the past few years would be impossible without the three-electrode vacuum tube.

The usual three-electrode vacuum tube consists of an additional electrode inside the bulb, made in the form of a metallic gauze, or spiral, called a grid, and placed between the filament and the plate. This makes it possible to increase or decrease the electron flow through a wide range. To the layman this simple control may sound somewhat insignificant; but the fact remains that it has been the important key to the action and the results obtained with modern vacuum tubes.

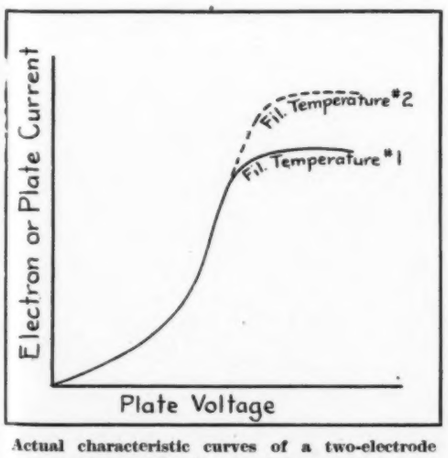
In order properly to understand this control action it is necessary first to consider what happens in a two-electrode tube having a good vacuum, when either the voltage or the plate current or the filament temperature is varied.



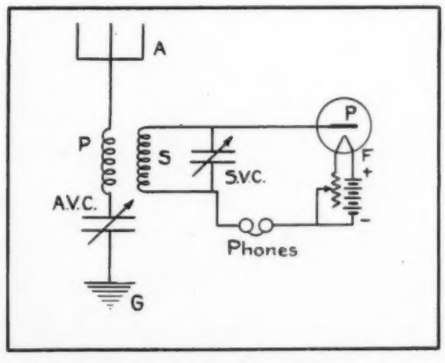
Wiring scheme for the two-electrode tube of the Fleming valve pattern.



The use of the grid in a three-electrode vacuum tube.



Actual characteristic curves of a two-electrode vacuum tube for two different filament temperatures.



Circuit for connecting Fleming valve for use as a simple rectifying detector.

PLATE VOLTAGE EFFECT

If the filament temperature is kept constant, a certain number of electrons travelling across the tube reach the plate, resulting in a certain volume of "space" or plate current. If the plate potential is increased the plate current is also increased until a value is reached where an increase in plate potential will give no further increase in plate current. This is fully illustrated in the left-hand curve diagram. The bend in the curve shows that with a certain plate voltage there is very small gain in plate current.

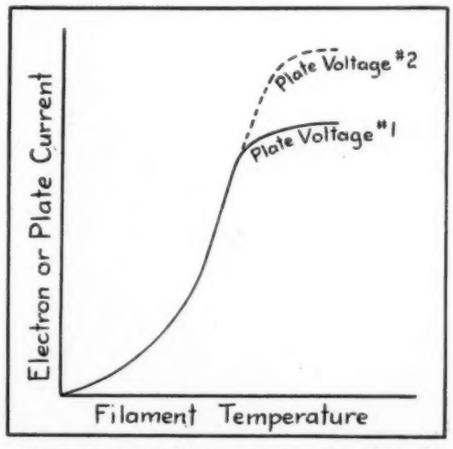
If the temperature of the filament is increased to a higher constant and the same plate potentials are applied, the plate current curve will coincide with that obtained at first until the bend is reached; then the curve will rise higher, as shown by the dotted portion of the curve in this diagram. This proves that the number of electrons sent out by the filament increases with the temperature, and the plate current is higher because more electrons have been made available to be drawn over to the plate.

Now if the plate potential is kept constant and the filament temperature is gradually raised by increasing the current flowing through it, the number of electrons or plate current is increased gradually with the filament temperature rise until the tendency of the filament to emit more electrons is neutralized by the plate voltage, and further increase in filament temperature fails to cause an increase in the plate current. This is fully appreciated in the right-hand curve diagram's full line curve. If the plate voltage is increased to a new value, it is found that the plate current rises higher before bending over, as shown by the dotted portion of the curve in this diagram, because it takes a larger space charge to offset the effect of the plate at the higher voltage.

GRID EFFECT

As stated before the "grid" or controlling electrode is interposed between the filament and the plate, directly in the path of streams of electrons which constitute the plate current. If a voltage is impressed on this grid by means of a third battery, shown at C in the center diagram, it is found that this will modify the space charge effect. The electrons passing from the filament to the plate must pass through the grid wires. If the grid is given a larger negative potential than the filament, it will repel or shed the electrons, but many will still pass through because of their high velocity, and will reach the plate. It is found that the plate current will still diminish if the grid is made still more

(Continued on page 279)



Actual characteristic curves of a two-electrode vacuum tube for two different voltages.

Ferments and Catalyzers

An Address Delivered at the University of Strasborg May 23, 1919

By Prof. Paul Sabatier, Member of the French Institute and Dean of the Faculty of Sciences of Toulouse

(Translated for the SCIENTIFIC AMERICAN SUPPLEMENT from *La Revue Scientifique* (Paris).

I esteem it a very great honor to address an audience in this University of Strasbourg, which once more belongs to France. I belong to that generation which, too young as yet to take up arms in the distressful days of 1870, felt more keenly than any other, in the very depth of the soul, the anguish of the mutilated Motherland, and which had continued from that moment to invoke the dawn of that day of justice and of glory when the stolen provinces, Alsace and Lorraine should be returned to France.

This joy is ours and it completes that joy for me that I, a French professor, should be able to take my seat in this chair in this palace, which was built upon the ruins of the former French Faculties, in order to contribute to the Germanization of this country.

In saluting today the new university whose task it will be to show forth the greatness of France and to carry on her mission of civilization, I cannot forget that in the nineteenth century Strasbourg was the motherland of illustrious savants whose names are imperishably recorded in the annals of chemistry, Gehrardt, Wurtz, Schuetzenberger, Friedel; and neither can I forget that one of the masters who taught chemistry in the former Faculty of Sciences of Strasbourg was the great Pasteur, to whose genius we owe the discoveries which shortly after were destined to open to biology and to the art of healing horizons of unlimited fruitfulness.

This name of Pasteur, which I was taught to venerate by my first master of chemistry, Henri Sainte-Claire-Deville, at the Normal School, is inseparable from the history of ferments, upon which field he sheds so much light; and it is in order to render homage to the memory of this illustrious son of France, as well as to honor at the same time that of my learned master, Marcellin Berthelot, that I have chosen for the subject of this address "Ferments and Catalyzers," a subject, moreover, to which the major portion of my scientific career has been devoted.

* * *

A great many chemical reactions are produced at once, as soon as the substances capable of giving rise to them are placed in contact, or else they require nothing more than a rise of the temperature of the system to occasion them. Thus when hydrochloric acid is poured upon calcium carbonate an effervescence at once arises though the temperature has not been raised, by reason of the liberation of carbon anhydride (carbon dioxide). A mixture of air and hydrogen will remain unchanged indefinitely at ordinary temperatures; but it need only be raised to a temperature of cc. 600°C. to occasion an abrupt and total combination of the two gases, i.e., an explosion. It even suffices to raise a single point of the mass to this temperature to produce the said explosion: the combination which occurs at this point produces enough heat to cause the whole mass to enter into combination.

But there are other reactions which do not take place spontaneously and which are not capable of becoming spontaneous, even when the temperature is raised—furthermore, certain reactions develop only with extreme slowness. But it often happens that these non-spontaneous or very slow reactions may be, so to speak, released like a spring and made to develop rapidly under the excitation of certain substances which, at first sight at least, seem to take no part in the action, since after the reactions have been accomplished these substances exhibit no visible modification and are capable of reproducing the same effects when used again.

Fermentations and catalytic actions belong to these special kinds of reactions. The first are set in operation by the presence of agents which are termed ferments, while the name of catylizers is given to substances which provoke the second sort.

FERMENTS

The name *fermentations* has long been given to those chemical phenomena of extended duration, in which the transformation of certain organic substances is accompanied by a sort of ebullition which takes place throughout the liquid mass which contains the said substances. Thus the juice of the grape, when left to itself in a vessel, soon exhibits spontaneously a more or less lively continuous effervescence due to the liberation of carbon dioxide, while it is observed at the same time that the saccharine substance contained in the grape juice gradually disappears while alcohol is formed in its place.

Our great Lavoisier was the first to establish the chemical equation of alcoholic fermentation, whose principle phenomenon consists in the splitting up of a saccharine substance, glucose, into alcohol and carbon anhydride. But when glucose is dissolved in water this solution may be preserved indefinitely without a similar breaking up—what then, is the cause of the phenomenon of division in the new substances observed in the grape juice?

If to the solution of glucose we add a few small fragments of the spongy and viscid substance known as beer yeast, which may be found in a vat of beer in process of fermentation, we immediately see bubbles of gas appear which become more and more abundant. The solid fragments of yeast floating in the liquid gradually increase and an active alcoholic fermentation is established which causes the breaking up of the glucose into alcohol and carbon dioxide; the latter disengages itself as fast as it is formed. This breaking up process is continued as long as there remains any glucose in the liquid, and if we remove a small quantity of the solid deposit occasioned by the increase of the minute fragments of the original yeast, this deposited substance will produce an identical fermentation in the same manner when transported into a fresh solution of glucose. It is obvious, therefore, that the fermentation has its origin in the presence of fragments of yeast or the solid deposit collected in the fermented liquid.

As early as 1836 the French savant, Cagniard de Latour, having examined under the microscope the yeast of beer and the transformation which it undergoes in the fermenting vats, recognized that this yeast consists of a collection of living cells similar to plant cells and endowed, like the latter, with the faculty of multiplying by means of budding, and he concluded that the action exerted by the yeast upon the glucose is probably due in some manner to its life and growth.

However, in spite of the capital importance of this idea, it was destined to be long ignored, and in 1839 Liebig, forming a synthesis of the more or less obscure explanations devised in previous centuries, promulgated the theory called communicated movement to explain fermentations in general, and alcoholic fermentation in particular. According to this theory, "the beer yeast which is added to the saccharine liquid is a putrefying substance and, generally speaking, all organic substances in a state of putrefaction transfer to the substances in their vicinity the state of decomposition by which they themselves are characterized."

Thus, according to this theory, the molecules of glucose, which are stable under ordinary circumstances, are disturbed by the molecular movements of the yeast which is rotting beside them, and under the influence of this disturbance they dislocate themselves into alcohol and carbon dioxide, just as a house of cards is made to fall by the vibration in its vicinity of a sonorous pipe or cord. Furthermore, this putrescent organic matter, whose decomposition occasions that of the glucose may be formed spontaneously in saccharine liquids, as in the case of that produced in the musts of the grape. The yeast was looked upon as a putrefying substance and but little attention was paid to the question of its origin and the conditions of its formation. This was merely replacing one form of ignorance by another, since no one knew what determined the putrefaction of the yeast.

But upon this murkiness of thought, which German science had but served to render more obscure, light was to be shed by French science in the person of Pasteur.

By an impeccable series of observations and experiments Pasteur established the fact that yeast is a living substance and not a decomposing substance and, furthermore, that it is not spontaneous in its origin, but is necessarily generated by germs brought from outside and that instead of rotting and decomposing it multiplies into new living cells, and that the action of the yeast is due to the life of these cells, this being the indispensable factor in the breaking up of the glucose: this breaking up is the necessary consequence of the life process of the cells when this process, being carried on within a saccharine liquid, has at its disposal only a limited amount of oxygen.

This fundamental rôle of the vital activity of micro-organisms is met with in a multitude of other similar reactions, other fermentations, and in each case the capital conditions specified by Pasteur are present, namely, the necessity of a germ from which the active living creatures are produced, and the intimate correlation between the life of these organisms and the chemical reactions which they excite.

Furthermore, these reactions are very various in character. The same glucose which is broken up into alcohol and carbon dioxide by the life process of the saccharomyces of the yeast may be broken up into exactly two molecules of lactic acid by the action of other cellular agents of much smaller size, and the transformation may become total if the presence of carbonate of calcium, by saturating the acid form, prevents the liquid from attaining a degree of acidity which is toxic for the ferment.

In other words, in order to change completely the nature of the transformation of the glucose, it was only necessary to change the species of the living organism. A third species of micro-organism gives rise to a much more complex reaction in which a portion of the glucose becomes hydrogenated and changed into mannite. Other living creatures, such as molds, acting upon the same solution of glucose in contact with air may simply occasion its entire oxidization into water and carbon dioxide.

I could add numerous examples of fermentations produced by the action of various micro-organisms, but I will confine myself to a single case, because it is a continuation of the alcoholic fermentation and because in this case also it was Pasteur who first defined its character—I refer to acetic fermentation. Dilute solutions of alcohol oxidize rapidly in the air yielding acetic acid under the action of the microscopic organisms called mycoderma aceti. This acid is the basis of the preparation of vinegar. In all these cases, which correspond to very various chemical actions—oxidizations, hydrogenations, hydrations, more or less complex decompositions—these actions are determined by the presence of living creatures, which at first sight appear to take no part in them except by their presence or their simultaneous development. These organisms are called living ferments or structural ferments.

Besides this first class of ferments others have been discovered which are not living organisms but consist of substances generated by living creatures, either vegetable or animal in origin, or micro-organisms; these substances are capable by means of their mere presenve, *in vitro*, of determining certain reactions entirely without any vital intervention, and these reactions would either not take place or would only be produced very slowly without their aid. These substances are called diastases or zymases.

A solution of cane sugar in water is stable and may even be boiled without undergoing a change in its properties. Its sweet taste remains intense; when traversed by a ray of polarized light it continues to rotate the plane of polarization to the right: Foehling's liquid reveals no appreciable reducing power in it. When allowed to evaporate so as to remove the water the cane sugar reappears in its original state.

But if to this solution we add a small portion of a saccharine liquid in which we have cultivated for a few days the black mould known as *aspergillus niger*, we very soon perceive that profound modifications have occurred in the liquid. The sweet taste is diminished in intensity, the rotation exerted upon the polarized light, which is first toward the right, diminishes and then passes over to the left, and Foehlings liquid' reveals a reducing power which becomes increasingly intense. When it has ceased to increase if we evaporate the solution we no longer recover the original cane sugar, but instead of this a mixture of

equal weights of two other sugars, glucose and levulose. Under the action of the diastase contained in the liquid which proceeded from the aspergillus, the molecule of saccharose has been decomposed by means of hydration into glucose and levulose.

This non-structured soluble ferment has been called *sucrase* or *invertine*. This is a substance which recalls albuminoid substances in its composition, since it consists of a combination of carbon, hydrogen, oxygen and nitrogen. It can be isolated in the solid state by precipitating it with strong alcohol.

A small proportion of sucrase is capable of transforming a large quantity of cane sugar into reducing sugar. Furthermore, the larger the quantity of sucrase the more rapid the transformation. As in the case of fermentation due to life the temperature greatly modifies the rapidity of action of the sucrase, and it is in the vicinity of 60°C .that this rapidity is greatest.

The following is another example of the same kind of ferment. When the germs of barley are treated with water a solution is obtained which possesses the property of liquefying starch paste. Particularly in the vicinity of 60°C. the latter is thus transformed quite rapidly into a semi-fluid liquid whose flavor becomes more and more sweet until finally its contains only glucose, which is capable of undergoing alcoholic fermentation under the action of beer yeast.

In the presence of this diastase of barley, to which the name of *amylase* has been given, the complex molecule of the starch is depolymerized into the more simple molecules of dextrine, which a consecutive hydratation transforms into glucose. A given portion of amylase is capable of liquefying 200,000 times its weight of starch.

Analogous properties are exhibited by a great many substances derived from plants or animals. They are generally soluble in water and for this reason they have been termed *soluble ferments*, a name which is often given to the diastases to distinguish them from the structured ferments. The kinds of work capable of being accomplished by the diastases are no less various than those performed by the structured fermentations. The two examples just cited, as well as many others, are connected with a molecular decomposition by hydratation.

But we find in plants oxydases which are capable of occasioning direct oxidization, and inversely chlorophyl, the green substance in plants must be regarded as disoyxdase, which reduces carbon dioxide into formol with the liberation of oxygen.

All living creatures are more or less provided with *hydrogenases* (the philothion of Rey-Pailhade), which are capable of occasioning the hydrogenation of certain substances. The part played by the diastases in the physiology of living organisms is of the most capital importance. The action of the various diastases is specific. However, it should be noted that certain ones among them are capable of effecting inverse results. The fundamental property of emulsine, which exists in sweet almonds, is the faculty of decomposing by hydratation the organic matters known as *glucosides* which are found plentifully in plants: there is a regeneration of glucose and of various other substances. This *salicine* is split up into glucose and *saligenine*. But M. Bourquelot has shown in recent years that the emulsine is capable of reconstructing by dehydratation the glucosides which it had decomposed. To accomplish this it is only necessary to make a change in the temperature and the degree of concentration of the liquids.

CATALYZERS

Catalytic actions are, as I have already said, reactions provoked by the presence of substances which to all appearance take no part in these reactions, and which are found intact after the reactions have been accomplished. These substances do not consist of living cells or of complex albumenoid substances derived from the life process, as in the case of fermentation, but, on the contrary, of very simple chemical substances, usually mineral in character, which in many cases are simple bodies. These substances are called *catalyzers*.

Catalytic actions are divided into two classes similar to those exhibited by fermentation. In the first class the catalyzers are intimately mixed, and remain so mixed, with the elements of the transformable system, while in the second class, on the contrary, the catalyzers are solid bodies acting by means of their surface upon gases or liquids. The first class includes catalyzers in homogenous systems, the catalyzers being liquid or dissolved. The second class comprises the solid catalyzers.

The processes of liquid or dissolved catalyzers develop themselves along lines parallel with those of the diasteses, from which they are distinguished by nothing except their non-vital origin. We find among them the same kinds of work done and the same laws regulating the rapidity of action, which increases, to a certain degree, proportionly to their mass.

The action of strong mineral acids, such as sulphuric acid, recall in all respects that of the hydrating diastases and just as in the case of emulsine this action may be exerted, according to circumstances, in one direction or the other. If a few drops of dilute sulphuric acid be added to a solution of cane sugar, a few minutes of ebullition suffice to accomplish a total transformation. The rotary power changes its sign and passes to the left, and Foehlings' liquid reveals a very intense reducing power. In the presence of the small quantity of sulphuric acid the sugar has been transformed by hydratation into a mixture of glucose and levulose; it is this mixture which is found present when the liquid is evaporated to dryness. The same transformation can be accomplished by sucrase, but the sulphuric acid performs it much more rapidly. Inversely the dilute sulphuric acid is capable of provoking effects of dehydratation. If we mix together equal molecules of alcohol and acetic acid the production of acetic ether which is correlated with a separation of water takes place only with extreme slowness: at the end of a day hardly one per cent. of the ether has been formed and more than ten years would be required to complete the reaction, but if a small percentage of sulphuric acid be added to the mixture the production of ether takes place almost immediately. In the presence of the cane sugar the sulphuric acid was a catalyzer of hydratation, while it is a catalyzer of dehydratation, on the contrary, with respect to the mixture of alcohol and acetic acid.

The work done by liquid catalyzers develops along parallel lines to that done by the diastases.

Certain ones, like the salts of manganese or cerium, act in the manner of oxydases. Many of them, including the strong mineral acids, which we have specially mentioned and also the strong mineral bases intervene as agents of dehydratation, of hydratation, or of complex decomposition. There is no longer any doubt as to the explanation of these catalyses, and their cause is always to be found, as my illustrious master Berthelot has fully established, in the formation of an unstable combination of the catalyzer with one of the constituents of the transformable system—a combination which serves as a stepping-stone and facilitates the desired reaction by orienting it. This "stepping-stone" or intermediate stage is visible in many of these reactions. In the catalysis of the destruction of dioxide of hydrogen in contact with an alkali, it is a combination of alkaline peroxides with hydrogen dioxide. In the case of the classic action of concentrated sulphuric acid upon alcohol it is the acid sulphate of ethyl which is stable at ordinary temperatures, but which when heated yields according to circumstances oxide of ethyl or ethylene, while at the same time regenerating the sulphuric acid; the latter then attacks the alcohol once more and the same results may be repeated for a very long time.

Explanations of the same sort are capable of being offered in all cases and doubtless entirely similar explanations will account for the action of the diastases, which are thus defined as substances apt to furnish unstable combinations with the constituents of the system which they transform.

The second class of catalyzers comprises the solid catalyzers acting upon liquid or gaseous systems. A very large number of these are known. I will mention three: platinum black, metallic nickel, obtained by the reduction of its oxide, and oxide of thorium.

Hydrogen dioxide or oxygenated water is a colorless liquid similar to water in its aspect. It tends to decompose into oxygen and water, but at ordinary temperatures this decomposition is very slow: For this reason hydrogen dioxide is commonly shipped in stoppered bottles without inconvenience; even at the end of a year its destruction would still be far from being complete; but if we throw into this liquid, which seems to be in a state of equilibrium, a pinch of the black powder known as platinum black, we at once observe a lively effervescence due to the disengagement of oxygen and at the end of a few minutes the decomposition of the hydrogen peroxide will be almost complete. Furthermore, the platinum black is recovered with no apparent change and is capable of reproducing the same effect indefinitely. Thus the platinum black is a catalyzer of deoxidization: it separates out oxygen.

Inversely, if we place platinum black in a shallow vessel which permits a free access of air and then allow a few drops of alcohol to fall upon it we observe that the latter is immediately oxidised, yielding aldehyde, whose characteristic odor is not at once perceived. The oxidization will be still more complete if the platinum black be slightly heated and a mixture of air and alcohol vapor passed over it; the oxidization will then proceed further than the aldehyde and will yield acetic acid, as does the microorganism, mycoderma aceti, and the heat disengaged by this oxidization is capable of raising the platinum to incandescence. Here again the platinum black is not changed and will continue to provoke the same reaction without ceasing. It is, therefore, a catalyzer of oxidization just as it was a catalyzer of deoxidization.

These same inversions of function are frequently met with and we shall find them in the following examples.

If through a glass tube, heated to a temperature of 180°C. or more, vapors of benzene carried along by an excess of hydrogen are passed, no change is perceptible after this passage. The hydrogen and the benzene reappear in integral form with their characteristic properties. If we condense the benzene we find that it still has its familiar odor and that it is immediately attacked by nitric acid. But if we place within the heated tube through which the gases pass a train of the pulverulent metallic nickel which is obtained by reducing the oxide of nickel by hydrogen or by carbon monoxide, we find that the benzene has disappeared completely as has also much of the hydrogen—a combination of the hydrogen and of the benzene has taken place, forming a new compound called *cyclohexane*, which has an agreeable odor, and which is not attacked by nitric acid. Furthermore, the nickel which has occasioned this effect exhibits no change in aspect or in properties, and is capable of recommencing the same operation. We say that the nickel is a catalyzer of hydrogenation, and I have been able to establish the fact that it exercises this function in the presence of an immense number of chemical compounds.

Inversely, if we pass vapors of the cyclohexane obtained in the manner just described over this same metallic nickel, raised to a higher temperature, we find that the cyclohexane is decomposed into hydrogen and regenerated benzene. Consequntly, the nickel is also a catalyzer of dehydrogenation. A change in the conditions suffices to invert its function.

The oxide of thorium is a white powder whose aspect recalls that of chalk. If we cover with this oxide a tube heated to temperatures above 300° C. and then lead vapors of alcohol into the said tube they are immediately decomposed by dishydratation, yielding ethylene, and this breaking up of alcohol into water and ethylene will continue so long as the vapors of alcohol are lead into the tube. If vapors of phenol be substituted, the tube being kept at cc. 400° C. there will once more be a separating out of water, together with the formation of a substance having an agreeable odor, which is employed in the art of perfumery, namely, *oxide* of *phenyle*.

It is likewise possible to accomplish the inversion in this latter case: a mixture of the vapors of oxide of phenyle and water vapor passed into the same oxide of thorium tube will produce, by combination with the water, a regeneration of the phenol, whose odor will be perceptible.

In this instance, therefore, the oxide of thorium is a catalyzer of dishydratation or of hydratation.

The work done by the use of solid catalyzers is extremely varied and includes most of the types of chemical reactions, oxidizations and disoxidizations, hydrogenations and dishydrogenations, condensations and molecular decompositions of various nature, isomerigations.

Furthermore the solid catalyzers capable of being used are very numerous and of highly various chemical nature; it must be remarked, however, that the most important are substances which are very simple of chemical constitution, metals in a finely divided state or metallic oxides.

What explanation can be given for the catalyses, thus effected by solid bodies? Solid catalyzers are generally pulverized and porous, and consequently it may be supposed that they are capable, like wood charcoal, of absorbing and fixing in their pores large quantities of gas. The physical explanation

(*Continued on page* 278)

Better Concrete—II

Motion Picture Studies of Existing Conditions; Suggested Improvements

By Nathan C. Johnson, Consulting Concrete Engineer

Concluded from our issue of October 25, No. 2284, page 251.

AIR VOIDS

One other feature is prominent in these photographs, namely an air void (a, Fig. 8) recognized by its spherical or spheroidal form) tucked away at a surface pocket in a sand grain. When this grain was first wetted this pocket was, of course, filled with air; and before it could escape the viscous water envelope went over it, imprisoning it by surface tension; and as diffusion progressed, moulding it for all time in solidified cement. By optical examination, boulders and sand grains of all sizes (Fig. 10) are found to have similar surfaces, full of pits and seams, which are admirable for attachment of cement if contact could be brought about, but potent for ill unless inclusion of air bells is prevented. If only some means, such as stirring or scrubbing, could be utilized to remove such impurities as air, considerable improvement in general quality should result, for although one void is very minute, its duplication billions of times at the surfaces of the billions of sand grains in a yard of concrete must be of great importance. Although the mind sees in increasing number other possibilities indicated by reasoning as probable means of bettering concrete, those previously cited have every element necessary for very substantial improvement, provided they can be put into effect.

Fig. 10.—Rough and Pitted Surfaces Common to Boulders and to All Sizes of Sand Grains. (Studied while turning to observe all sides.)

Starting experimentally with studies of the chemical union of cement and water, it is found that the process is initially of much greater rapidity at elevated temperatures. In Fig. 11, for instance, is shown interlacing crystal formations at 70 degrees F. after three hours, as contrasted with those at 50 degrees F. after ten hours; as the latter photographs show no visible change from their original appearance, temperature is evidently of great assistance in forming concentrated products.

INACTIVE CEMENT

It is further to be noted from these photographs that there is grouping together of individual particles, with less intense formation of cementing products, at the boundaries of such groups than at single particle. If such grouping were to exist in concrete, much of the cement would be taken from points where it should be usefully applied, since hydration would soon unite these groups inseparably. But since these groupings are always observed, such deprivation doubtless does take place, with resultant effect on the concrete. Further, examination of commercial powdered cements reveals small aggregations present in infinite number, due possibly to hydration from moist air and sticking together before it reaches a user's hands. Evidently such groupings should be forcibly broken up either prior to or during mixing; and evidently, also, there is little use in finer grinding of cement unless such groups can be broken up.

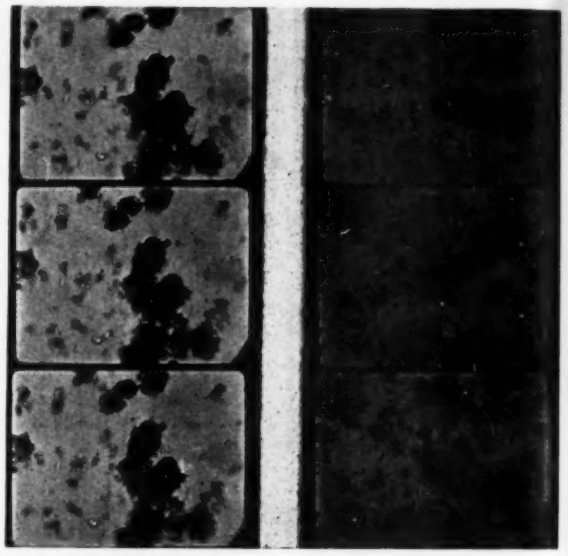
INTENSIVE HYDRATION

In addition to elevation of temperature, it is also found that intensive hydration can be brought about by violently stirring cement for periods longer than are usually employed, much as stirring "unstirred sugar" increased the sweetness of America's cup. And it is further found that while sand grains poured into water are lifted bodily by tenacious air bells resident at irregularities in their surfaces, such air bells can be removed and full contacting of water (or of cementing solutions) brought about not by stirring alone, but by such violent stirring as to cause attrition of particle on particle sufficient to bring about a scrubbing action. Considering these two phenomena in analogy, it is not improbable that the increased hydration of cement brought about by violent stirring is due to a removal of the protective skin from individual particles through such inter-particle attrition, bringing about earlier and more prolonged chemical activity, as well as by forcibly breaking up minute groupings before noted.

Combining these two benefits by removal of tenacious impurities and by increased hydration by violently stirring cement and sand together in water, there is present every element of an improved procedure in making concrete, particularly as such violent stirring raises by internal friction the temperature of the mass, with further increase of hydration.

THE EFFECTS OF VIOLENT STIRRING

But what is the actual effect and result of this as expressed in accomplishment? Aside from increased hydration products as noted by the microscope, there is formed a viscous, coherent mixture, not inclined to separate even though very plastic, with little or no formation at the surface of fluffy "laitance." Remembering the levitation of sand grains in water by attached air bubbles, as well as the lubricative effect due to the mobility of gaseous bubbles in a liquid, it is not improbable that removal of such bubbles, together with the heavier specific gravity of the fluid brought about through increased solution of cement, has overcome the tendency to segregation usually present. Furthermore, it is at once evident that if increase of hydration can be assured, greater tolerance in the percentage presence of water is permissible, with increase of plasticity and ease of working, and at the same time, assurance of a satisfactory result. Elimination of laitance and segregation on commercial operations would be of utmost importance, for materials so separated are almost valueless of themselves, but would have high value if retained in their proper places.

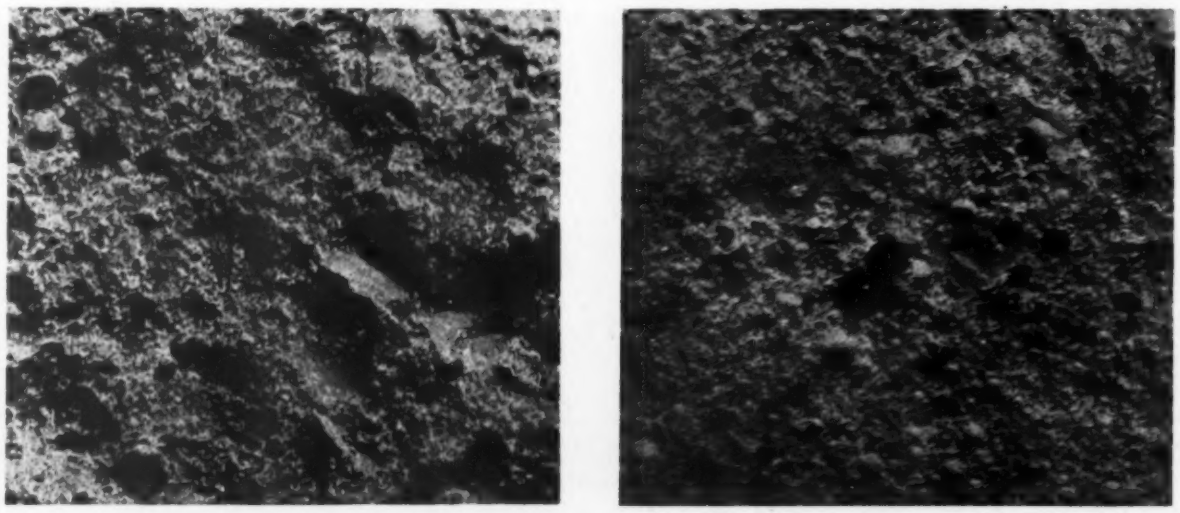


After 10 Hours at 50° F. (A) After 3 Hours at 70° F. (B).

Fig. 11.—Hydration of Portland Cement. Camera Interval 5 Min.

DENSITY

And a corollary effect should be better compacting and greater solidity of the mass, with commensurate strength and endurance. If the particles shown in Fig. 9 had been closer together, solutions of cementing products at the surfaces of sand grains would have been stronger, through nearness to the source. Furthermore, a greater number of strong sand grains would have been present in any given volume. This result is sought in commercial work by spading, tamping or rolling, the last named being found by study to be preferable where the form of construction, as in roadways, permits of its use. Yet, if increased hydration is realized, together with very thorough distribution of such hydration products and detachment of air bubbles from sand and stone, a minimum of such artificial compacting is found to be necessary for a substantial improvement in texture and strength. A comparison of mortars of like composition which carries its own message through the evident pulling-out of sand grains under stress in one and their facture through in the other, together with notations as to respective strengths, is shown in Fig. 12.



1:3 MORTAR—2-MINUTE PROCESS-MIX. 11.1% WATER. 2650 LBS. PER CU. IN.

1:3 MORTAR—11% WATER. 20-MINUTE HAND-MIX. 1830 LBS. PER CU. IN.

Fig. 12.—Comparative Textures after Crushing of Ordinary and Processed Concretes. × = 3 Diameters. Age, 28 Days.

EXCLUSION OF IMPURITIES

Furthermore, there should be less liability in such a product for points of

Fig. 13.—First Centrifugal Concrete-Mixing Machine in Action. 10-inch Diameter Bowl.

weakness to develop, either through the presence of an impurity at a center of disintegration, or through loss of uncharged water, or through unequal internal strain due to non-uniformity. Study confirms this reasoning, for mortars (stuccos) and concrete reveal that three branched cracks and their later ramifications are of primary origin, occurring at or about the time of set; and that they are induced by lack of uniform internal strength, for rupture comes suddenly, much as a sheet of paper might find relief from unbearable strain by rupturing abruptly about some point of weakness.

DISINTEGRATION AND SOFTENING

And not least, disintegrations and softenings should, with such material, be at least mitigated if not fully done away with. Disintegrations result from entrance of water into the body of concrete. Sea water carries so little material capable of attacking concrete that the entrance of many millions of gallons into the concrete is necessary for effective attack on a single cubic yard. Nor is the action of fresh water substantially different; and with this fluid, the same requirement applies. As for rupture by rusting of reinforcement, the existence of this fault argues conclusively that water has reached the steel through the concrete; but when that happens, rusting, with expansion and rupture, is to be expected. On the other hand, given a uniform, dense concrete, without water or air voids, or laitance seams, or shrinkage cracks, and the seas and lakes and rivers must confine their efforts to surfaces, instead of finding ready access to the interior, and with proportionate endurance.

But however much laboratory experimentation may prove, conversion into commercial terms only will be of substantial benefit.

LIMITATIONS OF MIXERS IN COMMON USE

Early in this effort, existing forms of mixers were discarded as ineffective and not susceptible of necessary changes. With time ever a limitation, the first thought was to substitute rapidity of action for customary slowness. By the same agency, also, it was hoped to effect the violence of action that seemed to be indicated as necessary to force reluctant materials into proper usefulness. In addition to rapidity of action, repetitive cycles on materials held compactly together to secure interparticle attrition were indicated. These constituted a new and different process from that heretofore used and demanded new means to effect it.

High rotative speeds imply centrifugal force as a concomitant. Centrifugal force would hold the mass of materials together, but would render inactive the usual drum mixer. Furthermore, a very small portion of available drum space in such machines is in active use, the over-capacity varying from 250 per cent. to 825 per cent. of the batch size in the products of ten different manufacturers. It is also found that much useful mixing time was consumed in charging and discharging, batches having to enter and leave through severely restricted openings.

The expedient was adopted, therefore, of using an open bowl, rotated rather rapidly on a horizontal axis. Centrifugal force would compact the rotating batch in the bowl and cause it to rise towards the top. At proper points, curved blades could cut off ribbons of material, diverting them to the center, so that repetitive cycles could be had. Discharge could be overside by utilizing the velocity of the mass, giving a high discharge, while the full diameter of the bowl would be available for charging, doing away with high elevation of material so that it would pass through a constricted spout. Furthermore, both mechanism and mass would be open at all times to observation.

CONCLUSION

The first mixer (Fig. 13) held thirty pounds of materials and was improvised from an iron potato kettle, and an iron tamper for a base, the bowl being rotated through one set of gears by a ⅛-H. P. motor which once operated an adding machine. Diverting blades supported by small pedestals overside completed the mechanism. Strangely enough, it was successful almost from the first; and results obtained with it were so interesting that larger units were undertaken.

A three-cubic-foot machine (Fig. 14) was then constructed; and later, a ½-yard machine. Trials and tribulations were not few in number, but they are of no import in this discussion. Suffice it that a most intense action was secured, showing in practical results the actuality of the theoretical needs indicated by the reasoning before set forth. And as bearing on the conservation of time in commercial operations, in Fig. 15 is shown the free overside discharge on a half-yard machine, the confining hood being removed, total discharge being possible in a few seconds.

This type of mixer is at present nearing commercial form. It has numerous operative advantages in addition to its more technical features, as here presented, notable among which are its low over-all height and its low center of gravity, all running gears and power being below the platforms and carried on a unit frame to insure alignment. Rotative speeds vary according to size of machine, being 80 R. P. M. for a half-yard machine and 110 R. P. M. for a 3-cubic-foot machine, with speeds for intermediate sizes lying between these limits. Endurance, contrary to what might be expected, compares advantageously with the present drum type at its best.

Fig. 15.—Discharging Concrete from ½-Cubic-Yard Mixer. Camera Intervals, 1/16 Second

It would be rash to say that this is the ultimate that may be achieved. It probably is far from it. But satisfaction is felt that a step forward has been made toward the utilization of "unstirred sugar" in concrete, with all that such an accomplishment fully realized would mean.

Fig. 14.—Three-cubic-foot Centrifugal Mixer in Action.

horsepower may be increased to 9 kg. by making the machine more efficient aerodynamically.

No improvement is expected as regards the weight horsepower ratio of the engine, this being taken as 1.4 kg. per horsepower for the complete power-plant when the engine is running all out; but the total consumption of petrol and oil will probably be reduced to 220 grams per horsepower hour for normal flight.

The weights of the planes and body will probably be reduced by the use of duralumin construction in place of wood.

Summing up, it is anticipated that the disposable load may amount to 49 per cent. of the total weight of the machine at the commencement of a flight.

The most favorable conditions for a flight are considered analytically.

In the first case, the machine is supposed to climb to 1,000 meters, after which the admission to the engine is kept constant, altitude control being provided, and the angle of attack is maintained at the value corresponding to minimum power. Under these conditions the machine will rise as the fuel is consumed. Expressions are derived for the altitude attained at the end of the flight, and for the power expended in rising to this altitude. This expenditure of power is stated to be only about 1 per cent. of the total power consumption, and is partly recoverable in gliding down at the end of the journey.

With an initial weight of fuel amounting to 30 per cent. of the useful load, and starting at 1,000 meters, the altitude finally reached would be about 4,000 meters. It is suggested that multi-engined machines could shut off one of their engines on attaining a sufficient height, and then descend to the altitude corresponding to the reduced power output.

The advantages of this method of making the flight are that the speed of the machine, and the efficiency of the airscrew remain constant, as does also the rate of fuel consumption, provided the altitude control is efficient. Moreover, in the case of one of the engines failing, it is possible to fly on the remaining engines, and still have a reserve of power.

The alternative method is to fly at constant height and at the optimum angle of incidence. In this case the speed would have to be gradually reduced, as the total weight of the machine decreased. This would have the disadvantage of increasing the unit fuel consumption of the engines, in addition to the objection to the decreased average speed.

A formula is obtained for the radius of flight under the first conditions, namely, those of gradually increasing altitude, and consideration is given to methods of construction, whereby the L/D ratio of the complete machine may be improved. It is considered that an ultimate value of 10 may be attained.—(Abstracted by the *Technical Review.*)

The Future of Traveling by Seaplane.

Writing in *L'Aeronautic*, R. Barth considers that, for reasons of safety, and to inspire confidence in the passengers, long-distance sea-flights will be accomplished by seaplanes in preference to ordinary land-type machines.

It is not expected that it will be possible to increase the initial loading of commercial machines much above 40 kg. per square meter of supporting surface, but it is anticipated that the loading per

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Scattering of Light by Carbon Particles in a Luminous Flame.—Experimental investigation of the properties of luminous flames, shows that such flames behave in an exactly similar manner to turbid media, and the results obtained for absorption and reflection by the luminous carbon particles are found to be both qualitatively and quantitatively in agreement with Mie's theory of turbid media.

[*Scientific Abstracts* from *Deutsch Phys. Gesell.*]

Ferments and Catalyzers.

(*Continued from page 275*)

which is adopted by many chemists and which continues to figure in works upon the subject is based upon this idea. Gases, or even liquids, are precipitated in the pores of the catalyzer and because of this they are subjected to a powerful pressure as well as an elevation of temperature sufficient to enable the reactions between the substances absorbed to take place. The catalyzer rejects the combined substance, absorbing fresh quantities of the transformable substances, and this process continues indefinitely. According to this theory the porous catalyzer is to be regarded merely as the accelerator, by means of compression and a local elevation of temperature, of a reaction which would have taken place slowly even without its aid.

For a number of reasons this theory can not be accepted. In the first place the porous condition is not always indispensable; platinum in the form of polished laminae is capable, like platinum black, of producing direct oxidizations which would not have occurred without its presence. The porous state is favorable because of the infinitely greater extent of surface, since solid catalyzers are capable of operating only by their surfaces.

Moreover the union of benzene and hydrogen in cyclohexane does not take place at any temperature: platinum black produces it only in a very poor manner, while nickel reduced from its oxide is capable of provoking this combination at a temperature as low as 60° C.

The most serious objection to the physical theory of catalysis is that the reaction accomplished in the same transformable system depends upon the chemical nature of the porous body which catalyzes it, and I have been able to discover entirely conclusive examples of this specificity.

The vapors of alcohol led over reduced copper heated to 250° C. are decomposed into hydrogen and aldehyde. If the copper be replaced by oxide of thorium the decomposition is entirely different, yielding ethylene and water.

The objection has been raised, to explain this difference, that in one case the catalyzer is of copper, i. e. a metal which is a good conductor of heat and of electricity, while in the other it is thorium oxide, a non-metallic powder, incapable of conducting electricity, which may perhaps play a part in these actions. But this reply, which in any event, boasts but a limited range, breaks down in the presence of another example which I have indicated.

The vapors of formic acid give rise to decompositions which are entirely distinct according to the nature of the metallic oxides which provoke them. With zinc oxide we obtain an exclusive separation into hydrogen and carbon dioxide. With titanium oxide the decomposition is exactly into water and monoxide of carbon. With other oxides, such as alumina or thorium oxide, one obtains an average of the two effects. The phenomenon thus differentiated cannot be the result of a mere elevation of temperature; and in this example the physical properties of the catalyzers, pulverulent white oxides having the same aspect, could not be involved.

Following in the path of my illustrious Master Berthelot, I have extended to solid catalyzers the theory which is accepted without dispute for catalyzers of homogenous system. Whatever they may be, catalyzers are the supports of temporary combinations which they provide with the constituents of the systems which they are to transform.

In the oxidizations which platinum catalyzes, as well as in the disoxidizations, the intermediate combination is a sub-oxide of platinum formed upon the surface of the metal, starting either with free oxygen or with oxygen yielded by a disoxygenable substance: this unstable oxide is destroyed in the process of oxidizing, or in liberating its oxygen, and regenerates the platinum, which may then reproduce the same oxide.

In the case of nickel, as well as of other metals in a state of division, which are capable though in a lesser degree, of exciting hydrogenations—copper, cobalt, iron, platinum,—the temporary compound is a hydride. In the reactions of dishydratation which thorium oxide enables us to accomplish so easily and in such numbers with the alcohols, it is a sort of alcoholate, comparable to the ethyl acid sulfate which intervenes, as we have said, in the catalysis in a homogeneous system of alcohol by sulphuric acid.

These unstable compounds are stages in the reaction which is seeking to be accomplished—stages which facilitate the descent of energy, but which are also capable of facilitating its re-ascent by the inversion of the function. These stages are often difficult to recognize, but it is possible to characterize them and isolate them in a considerable number of cases. Palladium hydride can be readily obtained as a chemical reality.

In the catalytic synthesis of acetones by the action of oxides upon the vapors of an acid at a temperature above 400° C. the intermediate combination is simply the salt yielded by the union of the acid with the oxide. Made beforehand, and then calcined at 400°C., this salt generates the acetone and regenerates the oxide. If the reaction of the acid upon the latter takes place at a temperature below 300°C. it gives rise to a salt which remains stable. Carried on at a temperature above 400°C. it yields acetone, since the salt is destroyed as soon as formed.

But in all these cases, as I have already observed, the combinations take place only upon the surfaces of the solid catalyzers: the action of the latter, therefore, is proportional to the surface; it will be especially great in the pulverulent state, and will be proportional to the fineness of the state of division.

It is by this theory of the temporary combination formed by catalyzers that I have been guided in all my researches.

I have demonstrated the strict analogy—I might even say the identity—of the soluble ferments with the soluble catalyzers. At first sight it appears that similarity of the same kind might be established between the "figured" ferments and the solid catalyzers. Certain resemblances exist, in fact, between the figured fermentations and the catalyses produced by porous bodies. The rapidity of action of the figured ferments is proportional, in a certain degree, to their mass—or, if the cells which compose them be identical, to the number of these cells. The rapidity of catalyses produced by solid bodies is proportional to their surface: but if they consist of a powder all of whose grains are equal it will be equal to the number of grains.

It is true in general of catalyzers, as of figured ferments, that there is an optimum temperature at which the action is most rapid and most complete. Thus the best results are obtained in the vicinity of 180° C. in the case of hydrogenations in contact with nickel.

Specificity of action exists in the case of figured ferments as well as in that of solid catalyzers. We have shown that copper dishydrogenates alcohols, while thorium oxide dishydrates them. It may be recalled also that glucose undergoes transformations which differ according to the organisms which are active, yielding either alcohol, lactic acid, mannite, or water and carbon dioxide.

The activity of the same kind of living yeast may be very unequal according to the more or less advantageous conditions which have presided at the production of the ferment or which concur in its life and development. In the same way it appears that solid catalyzers possess very unequal degrees of vitality, which may go so far as to transform their action. Nickel which has been reduced from its oxide at a temperature of less than 200°C. exhibits an extreme and disordinated activity which frequently exceeds the object in view; applied to the hydrogenation of aniline it generates chiefly ammonia and cyclohexane. Reduced in the vicinity of 350° C. it regularly changes the aniline into cyclohexylamine. Reduced at a red heat it is not very active and is no longer capable of modifying the aniline unless the temperature be raised to over 300°C., in which case it yields ammonia and benzene.

Very slight amounts of toxic substances suffice to paralyze the action of living ferments, and even to kill them. The same thing is true of pulverulent catalyzers, and particularly of metals in a state of fine division, which may be rendered entirely incapable of exerting any catalytic action by mere traces of other substances. An infinitesimal proportion of a derivative of sulphur, chlorine, or bromine in benzene will entirely prevent any transformation of this benzene upon the nickel into cyclohexane.

In the preparation of cyclohexanol by the hydrogenation of phenol upon the nickel all action was made to cease almost instantly merely by the pouring of bromine out of a bottle in another part of the laboratory at a considerable distance from the apparatus.

Because of all these resemblances the manner of action of the catalyses conducted by the aid of solid bodies in a finely divided state frequently recalls that of fermentation and even that of life. Minute causes which are sometimes very difficult to detect modify the course of the reaction, and one is tempted to ascribe this to the caprice of the catalyzer, just as one blames the ill-will of an animal which refuses to do the work demanded of it.

Three periods can generally be distinguished in hydrogenations by the nickel, as is also the case in many living fermentations. There is a first short period in which the catalyzer adapts itself to its function: it has all the appearance of exhibiting a hesitation as to the nature of the work to be accomplished and as to the manner of performing it. Then comes the period of useful work, which may continue for a very long time if care be taken to remove as far as possible all those causes which might alter the catalyzer. I have continued the transformation of benzene into cyclohexane for more than a month with the same nickel, extinguishing the grate at night and relighting it the next morning, but taking every possible precaution to insure the preservation of the metal. But however much care one may take infinitesimal traces of impurities finally alter the catalyzer slightly; slight secondary reactions which are imperceptible during a brief period but which may become appreciable in the long run may soil the surface of the catalyzer. Its activity diminishes with a greater or less degree of rapidity. This is the period of decline, and the old age of the catalyzer finally results in its total inactivity, i. e., its death.

But by the side of these analogies there exist profound differences between living ferments and solid catalyzers. The catalyzer always remains the same and can not decline except by progressive alterations. Structured ferments, on the contrary, grow, and this growth, which so greatly augments their useful action, may be highly important if the milieu where they develop is sufficiently provided with organic substances and mineral salts capable of insuring their abundant nutrition. It is an exception when such growth occurs in the case of mineral catalyzers; it might take place, however, if one practiced hydrogenation by means of an oxide of nickel which was very incompletely reduced—the amount of active metal would increase progressively with the reaction because of the simultaneous reduction of new quantities of the oxide. Does this analogy go further than in mere appearance? Precisely like the catalyzer the living ferment may be regarded as a temporary support of combination. The living cells of the yeast absorb the glucose, a portion of which is used for their own life while the large part is rejected, broken up into alcohol and carbon dioxide. Pasteur considered this decomposition to be the immediate and inescapable consequence of the anaerobic life of the ferment. Bertholet, on the contrary, thought that the life of the ferment generated a diastase, and that the breaking up of the glucose is due to the action of this diastase. All efforts to isolate this diastase had failed, doubtless because this diastase, generated in insufficient quantities by the cell, is immediately utilized by the glucose surrounding it, without accumulating in the cell as the sucrase accumulates which is secreted by the aspergillus niger and by beer yeast itself. But Buchner, merely by crushing the cells of the yeast, succeed in rapidly separating and isolating the diastase sought for, which is capable of decomposing the glucose into alcohol and carbon dioxide *in vitro*, entirely without the presence of life.

It would seem therefore that the structured ferments which are active in true fermentations, as also the living cells of plants and animals, are merely the creators of diastases, in other words catalyzes, and this conclusion enables us to hope for the discovery of mineral catalyzers capable of producing the same results as micro-organisms without the help of the latter.

This hope is already fulfilled in many cases: platinum black is capable of replacing the *mycoderma aceti* in the transformation of alcohol into acetic acid. Finely divided nickel or platinum is able to accomplish the oxidization of ammonia into nitric acid, just as nitrous and nitric ferments do.

SUMMARY

Living ferments produce diastases, as do many of the cells of the higher plants and animals.

Diastases are true catalyzers.

Catalyzers, whatever their nature may be, are substances whose temporary combination with one of the elements of a chemical system permits the repeated and indefinite transformation of the latter.

It must be admitted that we are still in ignorance of many things in this connection. We are almost entirely ignorant of the constitution of diastases,

which is generally very complex, but which it is permissible to believe, at least in the case of some of them, possibly has a direct relation with that of certain very simple mineral catalyzers which enter into their composition.

Even more, we are still far from having a precise knowledge of the biological phenomena which generate diastases in living cells for the purpose of facilitating or making possible the life of the latter. Little by little future researches in chemistry will shed new light upon this realm. But I have endeavored to show to you, very imperfectly indeed, how great a part French Science has played in our actual knowledge concerning these important questions.

I cannot close this address . . . without thanking you for having come in such numbers to listen to me and for having accorded me such kind attention, nor without saluting the University of Strassbourg, which it is my hope will carry to lofty heights the torch of French Science for the honor and progress of our ancient land of France.

Experimental Wireless Telegraphy and Telephony—VII.

(*Continued from page 273.*)

negative—sometimes it may be completely stopped. If the grid is given a positive potential instead of a negative one, more electrons than usual will be drawn toward the plate, resulting in a larger plate current. The grid charge limits the magnitude of the electrons by partly neutralizing the effect of the space charge, and a limit in plate current is reached much like that in the two-electron tube.

The saturation value of the plate current is assisted by the absorption of more or less electrons by the grid if its positive potiential is increased. This gives rise to a very small current called grid current.

THE MARCONI VT OR THE AMATEUR'S VACUUM TUBE

In the earlier days of vacuum tube manufacture the experimenter always faced uncertainty as to the quality of the tube he purchased. Some vacuum tubes were very sensitive, but had short life; others possessed varying degrees of sensitiveness and could not be relied upon for steady working. The majority of the so-called "good" tubes had to be operated at such critical filament temperatures to bring in strong signals that their life was only a matter of a few hours.

All these objections have been overcome in modern manufacturing methods, for engineers now know the materials best suited for the filament, grid and plate, and have developed improved methods of exhausting the tubes to a uniform vacuum.

So it is now possible to design vacuum tubes, structurally, to meet any desired conditions or requirements, so that all possess identical operating characteristics. The era of standardization has arrived, and this insures to all purchasers a uniform degree of sensitiveness and eliminates one of the chief objections to former types of vacuum tubes. At the present writing there is but one type of vacuum tube available to the experimenter, namely, the Marconi VT, which is shown in one of the accompanying illustrations.

The amateur experimenter requires a three-electrode tube of universal operating characteristics—tubes designed for specific services are not suitable. The Marconi VT is an all-round detector, one which can be used in any sort of a detection or amplification circuit. It operates efficiently over a wide range of plate voltages and at sufficiently low filament temperatures to insure long life. With proper care, it is claimed by the makers, this tube will last at least 1,500 hours with marked uniformity. It gives excellent results in amplification circuits.

The filament, grid and plate of the Marconi tube are made from materials from which all occluded gases can be readily removed during the process of manufacture. This prevents ionization and ensures stable operation. The Marconi VT is built to take the standard four-contact base, which makes all connections with the grid, plate and filament when the bulb is inserted.

The following precautions should be observed when operating the Marconi tube:

If one uses a battery in excess of 4 volts, care should be exercised not to exceed the stated filament current of 0.7 ampere. If a low-reading ammeter is not available, an approximate adjustment of the filament current can be made by cutting in all the resistance at the filament rheostat and putting 60 volts on the plate circuit. The resistance is then gradually cut out (with resulting increase of the filament temperature) until the telephones indicate the strongest signals. The plate voltage may be furnished by a bank of flashlight cells giving an electromotive force of approximately 60 volts. The telephones should be of approximately 2000 ohms.

Other values of plate potential and different filament currents can be tried, keeping the filament current within the stated limits. The filament should not be burned at higher temperatures than are necessary for strong signals, as lower temperatures tend to prolong its life. If the filament battery exceeds four volts it may recuperate sufficiently while standing still so that it will burn out the filament the next time it is used. Therefore the best practice is to cut in all of the filament rheostat before closing the filament circuit.

Measuring Visibility.

By Alfred H. Thiessen, Meterologist.

Visibility is the quality or state of being visible, and the visibility of any particular object depends in general upon the intensity of light reflected from the object toward the eye and the distance of the object from the eye.

The intensity of light varies during the day and during the year, and also varies according to the transparency of the atmosphere depending upon the presence of haze, smoke, fog, dust, rain, snow, and changes in the indices of refraction in sections of the atmosphere between the object and the observer.

This element of visibility is very important to aviators and gunners. It is important to know the visibility at night as well as by day, as aviators may desire to travel at night and even to land, and the intensity of lights at the landing field, and the efficiency of light thrown by flares depends upon the visibility.

There would, upon first consideration, seem to be very little difficulty in measuring visibility, because the observer is simply measuring how far he can see. But there are really many difficulties in the work, which will be reviewed in order.

The observers having objects located at definite intervals from the point of observation are trying to measure how far they can see. Leaving the personal equation out of consideration for the moment, they may determine either (1) the farthest object they just can see, or (2) the one that is just outside the range of vision. If they choose the first (1) method, then it is a question of how well the object should be seen, and if one should be able to see any of the details, as for instance the windows of a house.

During the late war the French used a scale of visibility which, with slight modifications, was adopted by the Meteorlogical Section of the United States Signal Corps.

The modified scale of visibility was:

	Kilometers
Very poor	0 to 2
Poor	2 to 5
Fair	5 to 10
Satisfactory	10 to 15
Good	15 to 20
Excellent	20 to 25

In this scale the visibility was said to be "Satisfactory" is one could see objects 10 to 15 kilometers away ,and so on, with the remainder of the scale.

The above scale has been superseded (Jan. 1, 1919) by the following scale of surface visibility adopted by the Meteorological Office of London, the Admiralty Meteorological Service, the Meteorological Service Royal Air Force, and the French Army Meteorological Service: [1]

Visibility Scale.	Objects not visible in good daylight beyond— Meters.	Miles.
0. Very bad	200	0.1
1. Bad	500	.3
2. Very poor	1,000	.6
3. Poor	2,000	1.2
4. Indifferent, ordinary	4,000	2.5
5. Fair	7,000	4.3
6. Good, above ordinary	12,000	7.5
7. Very good, unusual	20,000	12.4
8. Exceptionally good	30,000	18.6
9. No report (for telegraphic use	.....	.....
	Objects visible in good daylight beyond—	
10. "V" of Beaufort notation	30,000	18.6

In this scale the limits are carried out farther, which is certainly necessary in the lower limits of the scale, as in the case of the existence of fogs.

[1] From Met. Off. Circ. 32, Feb. 1, 1919, p. 3.

It has been the practice in measuring visibility to select objects found in the landscape, as barns, houses, trees, woods, lighthouses, etc., and it has been suggested that the typical objects subtend a vertical angle of 10′ and a horizontal angle of 2½′.

The practical objections to selecting objects at random are that they will differ in shape and color, do not lie in one line of sight, and do not have the same background. A white house can be seen farther than a brown house, both having the same size and shape, and both being in nearly the same line of sight. The visibility of either will depend greatly upon its background. Two objects exactly alike as to size, shape, and color, but one lying to the north and the other to the south, will be visible to different degrees. Another difficulty in using objects found in the landscape is that the observers become skillful in discerning what they are looking for, and if transferred to another station, where the objects will in all probability be different, they will, at the beginning at least, make observations not comparable with those made at their previous stations.

To overcome these objections, one may have a series of specially constructed targets, each series being alike for all stations. These targets may be a white circle painted upon a dark background, or any other specially designed object which may prove best for the purpose. The series at all stations should preferably lie to the north. The individuals of a series at a station will differ only as to size, which size should be determined by the angle which they should subtend. This will probably prove expensive, and a single target may be made to serve the purpose, and in many cases may be necessary, as it is extremely difficult to arrange a series in the same line of sight on account of intervening ravines, valleys, or hills.

This single target should be placed at 200 meters from the point of observation. It may be viewed through smoked glasses having 8 degrees of transparency. The smoked glasses take the place of sections of dusty atmosphere and may be so selected that measurements made on the standard object 200 meters away will be comparable to mesurements made with the naked eye on objects placed at various distances from the point of observations. For example, if object is visible to the naked eye and not through glass No. 1 the visibility is "bad". If the object can be seen with No. 6 but not with No. 7 then the visibility is "good".

Another method is to observe the target with a telescope so built that its power can be changed rapidly and as many times as there are degrees to the visibility scale. A suitable target would be one with a white background hatched with black lines. This target at a proper distance will appear gray, but if a telescope with sufficient power were used the individual lines would be discerned and the measurement would correspond to a certain degree on the visibility scale.

Observers are called upon to measure visibility at all hours of the day and night, and leaving out of consideration the transparency of the atmosphere, the intensity of light will vary from bright sunlight to the pitchy darkness of a cloudy night, and during the year from bright summertime to the darker days of winter.

In measuring visibility during the 24-hour day the following factors should be applied, owing to the variations in seeing mentioned in the preceding paragraph:

First. Angle of light rays illuminating the object or target.

Second. Condition of sky and cloudiness, twilight, starlight, and moonlight.

At nightime visibility may be measured by observing several lights in a row, the lights to be screened by glasses having varying degrees of transparency; or a single light could be used, the observer peering through smoked glasses at the point of observation. Experiments are now being made to develop a standard visibility measurer in which a screened light is viewed through glasses of differing opaqueness.

Revival of Indigo.

(*Continued from page 271.*)

to apply phosphatic manures. Apart from the dyestuff it yields, the indigo plant is now of importance as a green manure; and as a leguminous crop it also has its definite, natural place in the rotation.

Lac Cultivation in India.

The lac industry has for many years formed the means of livelihood of thousands of the poorer classes of India, especially those inhabiting the outskirts of the forests and other areas where the lac insect abounds.

Lac is a secretion produced by an insect which sucks the juice of plants and transforms it into resin. This secretion hardens on exposure to the air into a deep-red or orange-colored substance, semi-transparent, and breaking with a crystalline fracture. The insect belongs to a group commonly known as scale insects.

At the time of emergence the young insect is about 1/25 of an inch in length and deep-red in color.

After sluggishly wandering about and finding a suitable spot, it fixes itself and then thrusts its beak into the tissues of the stem and begins sucking the juice. The sap thus taken into the body is greatly transformed, and is given out uniformly through pores all over the body in the form of resin, which after a few days encases the insect completely. Female insects remain fixed once for all, but male insects emerge twice a year, sometimes as winged creatures.

The lac-bearing branches are cut off and placed on trees having a sufficient number of succulent branches. When the young insects have swarmed out, the old lac-bearing branches are removed and the resinous incrustation (stick-lac) is scraped off with a knife, ground in a mill, soaked in water, and washed. The pure animal resin (seed-lac) thus obtained is mixed with colophony and orpiment, cooked over a slow fire and drawn out into thin sheets, in which form it is commercially known as shellac.

The United States Vice-Consul in Calcutta calls attention to some interesting details furnished by Mr. C. S. Misra, first assistant to the Imperial Entomologist at the Agricultural Research Institute, Pusa, regarding the present condition of lac cultivation in the plains of India. During the last decade the industry has passed through many vicissitudes. Over-production, no doubt, contributed to a large extent to the lowering of prices of the crude material. Prices reached their lowest point about a year after the outbreak of the Great War—22 rupees per maund (about £2 per cwt.)—at which figure lac cultivation is hardly worth while. New uses were then found for shellac, and its exportation was limited, after which prices rose. With the steadying of prices of shellac the flow of the crude material has again become about normal. One result of the stimulus afforded by present high prices is that many persons have started the cultivation of lac in localities where success is doubtful, because the climatic conditions—an important factor in the development and subsequent acclimatization of the lac insect—are decidedly unfavorable. On the other hand, few new attempts at lac cultivation have been made in localities which at precent meet practically three-fourths of the world demand.

India is the only country in the world, says Mr. Misra, which supplies the market with shellac in its various manufactured forms. The Japanese have been trying to grow lac in Formosa, the Germans experimented with lac in Amani (German East Africa), and the Department of Agriculture in Egypt has also tried to introduce the industry there. The Indian Agricultural Research Institute furnished brood-lac for these three experiments, but definite information regarding their success or failure has not yet been received.

In the years when the prices rise, as was the case from 1905 to 1907, and again during 1915 and 1916, attempts are made to oust the natural lac from the market with a synthetic product, but these attempts prove unsuccessful, as the constituents of the synthetic article either cannot be obtained in bulk or the cost of manufacturing it leaves too small a profit. However, it is reasonable to expect that the partiality at present shown by consumers for shellac, which even in its standard form is more or less adulterated with foreign ingredients, such as colophony and orpiment, will at some time give way to a preference for seed-lac, which is a pure animal product, and in which impurities can be easily detected.

The Agricultural Research Institute at Pusa has conducted experiments in the treatment of pure lac by grinding stick-lac to standard size, soaking and washing in water, adding monohydrated sodium carbonate, then aerating, and frequently turning in the shade until thoroughly dehydrated. Samples of the product, which was a beautiful pale brown in color and considerably superior to the seed-lac obtained without the addition of the alkali, were judged by a London firm to be twice the value of the untreated product.

It is pointed out by Mr. Misra that the supply of stick-lac can be increased by removing all the lac from the trees a fortnight before the swarming of the young insects takes place and putting it on trees already pruned for the purpose, and then not gathering the stick-lac until after the swarming occurs, instead of before, as has often been done. Prior to 1908, when lac dye was a marketable product of considerable importance, it paid to remove the stick-lac before swarming and when rich in coloring matter; but now, with the introduction and extensive use of aniline and other dyes, lac dye has sunk into insignificance. Experience has shown that stick-lac obtained from pruned trees is richer in resinous content than that obtained from unpruned trees, and that the successive broods reared on pruned trees are not so liable to disease. It is also a noteworthy fact that brood-lac should be obtained from a locality having similar climatic conditions to those obtaining in the place to which it is to be transported, and that brood-lac does best when transferred to a tree of the same species as the one from which it was taken.

The heaviest lac production is in the northeastern section of the Indian Peninsula, in parts of the United Provinces, Central Provinces, and the Province of Bihar and Orissa. There is also an area in Eastern Burma, one in Western Sind, and a section of Central Assam, where quite large quantities of lac are collected, as well as smaller quantities in scattered sections.

The value of the shipments of lac (mostly shellac) from India in 1916-17 was £1,819,000, 78 per cent. going to the United States, which has been the largest buyer of Indian lac for the last twenty years.

The extent to which export values have risen is clearly seen in the 1916-17 trade figures; for, with a total value of £704,000 greater than in 1915-16, the quantity of lac shipped from India was 35,971 cwt. less. Exports to the United Kingdom—India's second best customer—showed a decline of nearly 50 per cent. in quantity in 1916-17. Practically all the lac exported from India now goes out through the ports of Bengal, as the following table shows:

Exported from—	1915-16. cwt.	1916-17. cwt.
Bengal	415,781	380,701
Bombay	45	94
Sind	678	478
Madras	723	2
Burma	93	74
Total	417,320	381,349

In 1917-18, India's shipments of lac of all kinds (excluding lac dye) reached the record value of £2,451,000, accompanied by a drop in quantity exported to 322,420 cwt.—(From the *Journal of the Royal Society of Arts.*

Causes and Preventions of Fires and Balloons

(*Continued from page* 258.)

the balloon, a slightly louder "pop" was heard near the valve, which, by this time had been raised about 3 feet from the floor. Bluish vapors arose from a small area a little above and behind the valve. Sergeant Hamilton gathered the valve and fabric in his arms. The vapor ceased and the fabric which had begun to blister cooled off. There were no visible flames on the outside, and the inner surface was later found to be only scorched.

A more violent explosion occurred almost immediately after, and smoke began coming from the surface of the balloon on the rear left side above the ballonet. The hydrogen was turned off, and the company left the hangar. However, the smoking soon ceased, so after a few minutes when the danger had apparently passed, the balloon was removed to a nearby field and moored down. It was found to be scorched on the right side near the valve, and on the rear left side of the ballonet.

Further experiments and inspection appeared to prove that the explosions which occurred in the hangar were produced as the result of explosive mixtures formed by the release of air contained in the pockets which had been formed as a result of the freezing together of the fabric. The electric sparks which caused the ignition appear to have been produced by the tearing apart of the frozen surface of the fabric.

The larger amount of explosive mixture which formed in the balloon when outside the hangar resulted from an opening having been made at a place in the balloon other than at the top, while the balloon was only partially filled. The circumstance was further aggravated by there being two openings, the valve and the appendix. It is probable that the spark primarily responsible for this explosion resulted in the same way as those which occurred in the balloon when in the hangar.

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Table of Contents

	PAGE
Causes and Preventions of Fires in Balloons—by Dr. W. F. Swann	258
Stunt Flying and the Commercial Pilot—by Lieut. F. T. Courtney, late R. A. F.	259
Sound Emission from Airscrews—by Prof. G. H. Bryan, F. R. S.	259
Atoms and Molecules—by Jean Becquerel, Prof. at the Museum of Natural History in Paris: Illustrated	260
"Storms of Cold" and Their Paths	263
Some Odd Modes of Travel—by James M. Treadwell: Illustrated	264
Sex in Eggs and Chickens—by Michael K. Boyer	265
The Value of Lupine in the Cultivation of Poor, Light Land	265
The Welding of Glasses	265
The Physiology of Sneezing—by A. P. Brubaker, M. D.	266
Monistic and Dualistic Conceptions of the Stellar Universe—II—(concluded)	267
Earth Effect on the Sun	267
Petroleum Refining—by R. W. Cunningham: Illustrated	268
Electricity in Agriculture	269
The Use of Raw Tars as Fuel for Diesel Engines—by Harold Moore, M. Sc. Tech.	270
Revival of Indigo	271
Experimental Wireless Telegraphy and Telephoning—VII—by Louis Gerard Pacent and Austin C. Lescarboura—Illustrated	272
Ferments and Catalyzers—by Prof. Paul Sabatier	274
Better Concrete—II—by Nathan C. Johnson—Illustrated	276
Measuring Visibility—by Alfred H. Thiessen	279
Lac Cultivation in India	280

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mark
the

y,
Y.

PAGE
258
259
259
260
263
264
265
265
265
266
267
267
268
269
270
271
272
274
276
279
280